FINAL REPORT P-44458/G

Wastewater Characteristics of Five Peat Dewatering Processes

for

Environment Canada

By

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Wastewater Characteristics of
Five Peat Dewatering Processes
(Proposal P-4458/G)

for

Environment Canada

SUMMARY

The exploitation of Canada's vast peat reserves through wet mining and subsequent dewatering to produce a peat derived fuel has received increasing interest. Five dewatering technologies are being investigated as possible elements in the production of peat derived fuel. Three processes are based on thermal pretreatment of the peat, viz. wet oxidation by the Ontario Research Foundation, wet carbonization by the Institute of Gas Technology and the "low-severity" process of The Université de Sherbrooke. The two non-thermal processes are the McGill University's dewatering using microbial products and the rotary press developed by the Centre de Recherche Industrielle du Québec. As peat contains up to 90% moisture, the dewatering of peat results in the discharge of copious wastewater. The principal objective of this work was to characterize these effluents.

The chemical and biological characteristics of the wastewaters discharged by the five peat dewatering processes varied greatly. The wet oxidation and wet carbonization produced strongly coloured effluents with high levels of biochemical oxygen demand, ammonium and phenolic compounds. Some acid extractable priority pollutants and toxic heavy metals were detected in these effluents, but not at alarming levels. Each of the three thermal processes were reported to have a high acute toxicity in the Microtox bioassay and to fish. However, they are likely amenable to biological wastewater treatment.

The two non-thermal processes were found to be non-acutely toxic in the Microtox bioassay. The CRIQ pressate was heavily laden with suspended solids and strongly coloured. The filtrate provided by McGill University was very low in all pollutant parameters measured, including colour.

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Caractéristiques des eaux usées
dans cinq procédés de déshydratation de la tourbe
(Proposition P-4458/G)

pour

Environnement Canada

RESUME

L'exploitation des vastes réserves de tourbe du Canada par extraction minière à l'état humide suivi d'un traitement de déshydratation dans le but de produire un combustible à partir de la tourbe revêt un intérêt grandissant. Cinq techniques de déshydratation pouvant permettre la production d'un combustible à partir de la tourbe sont actuellement à l'étude. Trois de ces procédés se fondent sur le pré-traitement thermique de la tourbe, à savoir l'oxydation en milieu liquide développée par la Fondation de recherche de l'Ontario (Ontario Research Foundation), la carbonisation en milieu liquide mise au point par l'Institut de la technologie pétrolière (Institute of Gas Technology) et finalement le procédé de "Low-severity" de l'Université de Sherbrooke. Les deux procédés non thermiques sont la déshydratation utilisant des produits microbiens, de l'Université McGill et la presse rotative mise au point par le Centre de recherche du Québec. La tourbe pouvant contenir jusqu'à 90% d'humidité, sa déshydratation entraîne des quantités importantes d'eaux usées. Ce travail a pour principal objectif de présenter les caractéristiques de ces effluents.

Les caractéristiques biologiques et chimiques des eaux usées entraînées dans les cinq procédés de déshydratation de la tourbe varient beaucoup. L'oxydation et la carbonisation à l'état humide produisent des effluents fortement colorés avec une demande biochimique en oxygène et en composés phénolés et ammoniaqués extrêmement élevée. Des polluants majeurs pouvant s'extraire à l'acide et des métaux lourds toxiques ont été détectés dans ces effluents à des taux qui ne sont pas alarmants. Ces trois procédés thermiques présentent un haut degré de toxicité. Néanmoins, ils sont bien adaptés au traitement biologique des eaux usées.

Les effluents des deux procédés non thermiques se sont avérés non toxiques dans la méthode d'essai utilisée. Le pressat du CRIQ contenait de lourdes quantités de solides en suspension et était fortement coloré. Les taux de polluants mesurés du filtrat fourni par l'université McGill, ainsi que la couleur, se sont avérés très faibles.

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1. INTRODUCTION

1.1 Background

Canadian reserves of peat have been reported to be the largest in the world (Kivinen and Pakarinen, 1980). Based on air inventory data, peat resources in the ten provinces are estimated at approximately 90 billion tonnes (at 50% moisture) (Tibbetts and Ismail, 1980). In Canada, peat is not employed as an energy source. However, in Ireland, Finland and the USSR, significant portions of those countries' national energy needs are met by peat fuel utilization (up to 25% in the case of Ireland).

Peat as it is found in deposits has a high moisture content (up to 90%) and, in order to be utilized as a fuel, most of this water must be removed. Peat, however, is rather hydrophilic and, hence, difficult to dewater by conventional mechanical equipment. This is especially true of highly humified deposits (which also have higher energy content and lower value for horticultural uses). Given Canada's climatic conditions (which do not favour solar drying) alternative dewatering technologies are required.

A notable degree of interest has developed in Canada recently, principally within the National Energy Program, in the development of technology to wet mine peat, dewater the slurry and produce either a high density lower moisture fuel or a feedstock for gasification. Three processes funded by the NRC in FY 83/84 were

(1) low-severity technology at the Université de Sherbrooke,
(2) partial wet oxidation at the Ontario Research Foundation (ORF) (both thermal processes), and

(3) a biological bench-scale process to enhance dewaterability.

These processes will generate various filtrates, pressates and/or vapour condensates as by-products or effluent streams.

In addition to the three processes mentioned, there is also a project underway at the Centre de Recherche Industrielle du Québec (CRIQ) to optimize the performance of a demonstration scale high pressure (up to 2000 psi) mechanical press.

Wet carbonization of peat to enhance dewaterability is another process receiving wide attention. Various European and American groups are investigating or employing different forms of the technology. The Institute of Gas Technology, in Chicago, Illinois, is currently operating a pilot scale wet carbonization process on Minnesota peat.

As noted above, peat is mainly water and, hence, any dewatering process will result in the discharge of large volumes of wastewater, relative to the potential peat product stream. The environmental implications of these wastewaters is potentially crucial to the various peat dewatering technologies, both in terms of their potential ecological impacts and their economic viability.

This project was conducted in response to a Request for Proposals developed by Environment Canada (DSS File Number 075C. KE205-3-P063). The objectives of this work (as detailed in ORF Proposal P-4458/G) were to co-ordinate and conduct an analysis program required to chemically characterize wastewater streams from the five peat dewatering research projects noted above.

1.2 Selection of Parameters for Analysis

The specific parameters analyzed for in this project were chosen principally on the basis of discussions with the various researchers, Environment Canada personnel (most notably Mr. Ken Conn of the Canadian Wastewater Technology Centre), and ORF's prior experience with peat processing wastewater analysis and treatment. Another factor was the size of sample provided by the researchers, which, in the case of the bench scale projects conducted at the two universities, precluded the analysis for a number of parameters.

The conventional wastewater parameters analyzed were designed to assess discharge impacts and treatment requirements for each wastewater stream. These included residues (total, filterable and volatile), chemical and biological oxygen demands, nutrients (nitrogen and phosphorus), phenolic substances, and oil and grease. Total volatile acids, sulfate, sulfide and alkalinity/acidity were also analyzed. These parameters are generally employed in the evaluation of treatment by anaerobic digestion. Anaerobic digestion of peat processing wastewaters has been the subject of recent and continuing work at Ontario Research Foundation, Institute of Gas Technology and ADI Limited.

Colour is considered to be a potentially important parameter in peat processing wastewaters due to the often highly coloured nature of waters contained in well humified peats and prior experience at ORF (Sheppard, Gallo and McKim, 1980). This experience had shown that wastewaters from the partial wet oxidation of peat contained biologically refractory colour producing substances. Humic and fulvic acids (generally present at high concentrations in peats) are described as being highly coloured (Fuchsman, 1980). Interest in these parameters also rests on their association to phenolic hydroxyl groups.

Metals, specifically toxic heavy metals, are of interest in any peat process wastewaters in terms of discharge criteria or treatability. Metal content, however, is directly determined by the composition of the peat deposit. A review of literature on the pollution potential of the peat resource had indicated that levels of heavy metals sufficiently high to be of concern have been reported (Washburn and Gillis, 1982). The same authors had noted that "no levels of specific organic contaminants in natural peat or peat waters were reported". Results reported on wet carbonization wastewater composition had noted a number of phenolic compounds in an IGT sample (Smith, 1981). Acid extractable priority pollutants (as defined by the U.S. Environmental Protection Agency) was chosen as a group of representative phenolic compounds to be determined in the wastewater samples.

The recovery of by-products from wastewater streams can often be an attractive alternative to waste treatment. Several groups have reported interest in the use of the organic content of peat processing wastewaters as a fermentation substrate for the production of single cell protein (LeDuy, 1981, and Martin, 1983), ethanol (LeDuy, 1983), and butanol (Forsberg, 1984). High pressure liquid chromatography (HPLC) was used to determine monomeric sugar substrates, e.g. glucose and xylose, and related organic acids, e.g. galacturonic and glucuronic acids. HPLC was also employed to identify furfural and hydroxymethyl furfural. These compounds are degradation products which are known to be inhibitory to some fermentations.

Lower molecular weight organic acids, e.g. formic, acetic and propionic acids are common products of both wet carbonization and wet oxidation. These compounds and other organic acids may be detected by ion chromatography. Volatile organic acids are potentially important by-products of thermal pretreatment of peat. They are also of interest as intermediate compounds in the anaerobic digestion of organic wastes.

Inorganic ions may also be detected by ion chromatography by employing a different column: common salt anions, e.g. halides, nitrate, nitrite and phosphate are detectable by this technique. These compounds are of interest to the biological treatment of wastewaters in their roles as nutrients and as possible causes of inhibition through salt imbalances.

A final and very useful parameter chosen for this work was a microbial bioassay, using photoluminescent bacteria. This technique offers a quick measure of acute toxicity and, thus, a general indicator of potential environmental problems.

2. PEAT DEWATERING PROCESS DESCRIPTIONS

2.1 Partial Wet Air Oxidation

Process Background

Wet air oxidation is the basis of a number of peat processing technologies. It has been evaluated as a form of pretreatment to enhance peat dewatering, and for the direct production of energy (heat and electricity). Wet air oxidation can accept peat over a wide range of consistencies (from 3 to 10% solids content). The process achieves the oxidation of organics at elevated temperature and pressure in the presence of oxygen (from the air) and water.

The wet oxidation process employed for this work is based on the Wetox(R) process, which has undergone development at the Ontario Research Foundation over the past decade. The first commercial unit for the process has recently been installed to partially destroy toxic organic substances in an industrial wastewater prior to biological treatment.

Wet oxidation of peat has been conducted on a pilot scale for a number of peats and operating conditions (Sheppard, Gallo and McKim, 1982). Figure 2.1-1 shows a schematic of the process as proposed and evaluated for the partial wet oxidation of peat to yield a solid fuel product. Wet mined peat is preheated by steam injection before partial wet oxidation. Heat generated in the wet oxidation reactor is converted to steam and the wet oxidized peat slurry is then mechanically dewatered to 50% solids by vacuum filtration and hydraulic press. Filtrate, pressate and vapour phase condensate are collected and treated by an

anaerobic filter. Biogas evolved in the anaerobic filter (75% methane content) is used to reduce the peat product to 33% moisture. The process recovers 66.5% of the peat feed energy in the form of the dewatered fuel product.

Process Conditions

The partial wet air oxidation trials were conducted at the Ontario Research Foundation, located in the Sheridan Park Research Community, Mississauga, Ontario. Mr. H. Robey, P.Eng., was responsible for the programme. The trials were conducted during the period between November 29, 1983, and January 5, 1984, and are described in ORF Report P-4389/G (Wet Oxidation of Peat-Liquid and Solid Fractions for Environmental and Energy Studies to National Research Council Canada, April 3, 1984).

Figure 2.1-1 shows the locations of sampling points. The peat feed was slurried with bog water and pumped to the wet oxidation reactor using a Moyno(TM) pump. The reactor was a 7 litre stirred autoclave into which air and slurry were continuously fed and liquid and gaseous products continuously withdrawn. The gas phase effluents were passed through a condenser and the condensed vapours collected. Liquid effluents were also heat exchanged and collected. The cooled liquid effluents were vacuum filtered (through a Buchner funnel employing number 541 Whatman filter paper) and the filtrates collected. The filter cakes were further dewatered by means of a Carver Laboratory hydraulic press operated for two minutes at 2 MPa.

A range of operating conditions were evaluated over the program. Six trials were conducted, three each for two peats of different degrees of humification. The peats were obtained from a bog

located approximately 40 km west of Quebec City. One was a "medium" humified peat with a von Post classification of H5-H6 and a "high" humified peat of H8-H9 von Post.

A range of operating temperatures were employed for each of the peat samples. Trials were conducted at 180, 200 and 220°C. Tables 2.1-1 and 2.1-2 summarize the conditions employed and the overall mass balances for the medium and high humified peats respectively.

Sample Handling

Peat feed slurries were sampled from the homogenized feed tank. Sample volumes were approximately 5 litres. Sampling of liquid and condensed vapour phase effluents was commenced after three reactor volumes were processed through the wet oxidation reactor at the required temperature to assure steady-state conditions. The liquid effluents were filtered (to yield filtrate) and the filter cakes subsequently pressed (to yield pressate). In the first wet oxidation trial, the filtrate and pressate were analyzed separately. No significant differences in the concentrations of potential pollutants (with the exception of total and volatile suspended solids) were noted between the two samples (Note Table 4.1-3). Filtrates and pressates from the five subsequent wet oxidation trials were combined for analysis. Twenty litres or more of combined filtrate and pressate were collected over each trial. The volumes of vapour phase condensate collected ranged from 300 mL to over 5 litres.

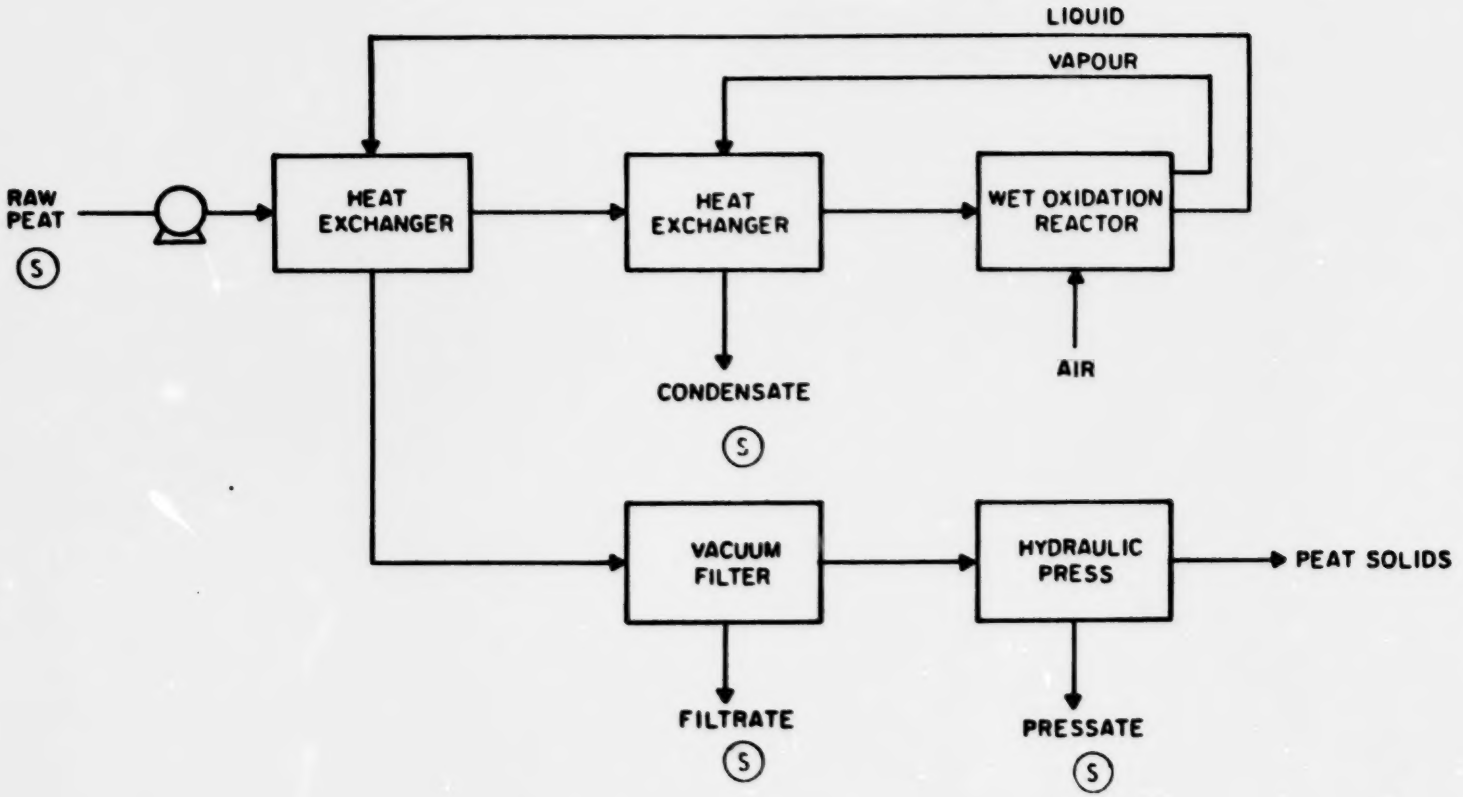


FIGURE 2.1-1

ORF - PARTIAL WET OXIDATION / DEWATERING OF PEAT

(S) - Sample Point

TABLE 2.1-1 - High Humified Peat

Test Conditions and Mass Balances

Run No.	1	2	3
Reaction Temperature, °C	220	200	180
Residence Time, minutes	22.7	20.8	17.9
Peat Feed, kg	56.1	21.6	33.6
Liquid Phase Effluent, L	46.8	19.0	32.2
Vapour Phase Effluent, L	9.3	2.7	1.0
Filtrate, L	39.8	15.4	27.1
Pressate, L	1.8	0.75	1.18

TABLE 2.1-2 - Medium Humified Peat

Test Conditions and Mass Balances

Run No.	4	5	6
Reaction Temperature, °C	220	200	180
Residence Time, minutes	19.2	17.2	14.0
Peat Feed, kg	23.4	29.0	21.6
Liquid Phase Effluent, L	20.8	28.0	21.5
Vapour Phase Effluent, L	2.5	1.0	0.32
Filtrate, L	17.7	23.0	16.0
Pressate, L	1.03	1.15	1.6

2.2 IGT Wet Carbonization Process

Process Background

Wet carbonization of peat is an old process. A commercial wet carbonization plant was operated in Scotland from 1915 to 1920. This batchwise operated plant was finally closed in 1921 due to fouling and corrosion problems. Commercial exploitation of peat utilizing wet carbonization has been conducted in the Soviet Union since the 1930's (Mensinger, 1980).

Extensive pilot operations have been conducted in the past 10 years using two competing wet carbonization processes, viz. the Koppelman process and the JP Energy process. The latter process is named for the Finnish consortium (JP Energy OY) which is developing and marketing the technology.

The Institute of Gas Technology (IGT) in Chicago, Illinois, has been conducting bench scale studies for the past several years. More recently, the IGT has built a continuous wet carbonization plant for the processing of peat. This plant does not employ the proprietory reactor nor the preheating tower of the JP Energy process. It does, however, follow the basic steps of the Finnish design. A schematic of the IGT process is shown in Figure 2.2-1.

The IGT pilot scale wet carbonization process has an approximate design throughput of 18 kg/hour of peat (dry basis). Feed to the process is macerated peat at an approximate consistency of 5%. The peat slurry is delivered by a low pressure pump through a shell and tube heat exchanger (where sensible heat is recovered from filtrate) and then through a flash condenser (where sensible and latent heat are recovered

from wet carbonized peat). This heat exchanger does not, under proper operating conditions, permit direct contact of the liquid effluent and peat slurry.

The wet carbonization is accomplished in a series of four stirred reactors. The peat (preheated to approximately 150°C) is delivered by a high pressure pump to the first reactor. High pressure steam is also injected into the reactor. Sufficient steam at 7900 KPa is added to maintain the reactor at 230°C. A retention time of 20 minutes is typical for the process.

A comparatively small vapour stream is removed from the last wet carbonization reactor. This stream is collected as a condensate. The larger liquid phase stream is flashed and cooled to approximately 90°C in a heat exchanger, and then dewatered in a 30 cm plate and frame filter. A small amount of condensate is also collected from the flash unit. The filtrate is then heat exchanged with the incoming peat slurry.

Processing Conditions

Wet carbonization trials were conducted on January 19, 1984, at the pilot plant facilities of the Institute of Gas Technology, Chicago, Illinois. Feed peat for the trial was obtained from a bog near Floodwood, Minnesota. Wet carbonized peat from the process was dewatered the following day using a plate and frame filter press.

The temperatures of the wet carbonization reactors were maintained at 242°C, 236°C, 233°C and 229°C for the first through fourth reactors respectively. The system was pressurized to 3.45 MPa with steam injection. Total liquid retention time in the four reactors was 48.6 minutes. The first heat exchanger (used to cool filtrate) was not used in this trial.

It was revealed some time after completion of the trial that a portion of the feed material had short circuited the process within the flash heat exchanger. The wet carbonized product stream contained about one third raw peat.

Figure 2.2-2 shows the overall mass balance reported for the trial. The mass balance does not include the observed short circuiting.

Sample Handling

Samples of filtrate (2 x 20 L), peat feed slurry (2 x 20 L) and condensate (5 L) were held in cold storage after processing in Chicago from January 20 to 25, 1984. The sample containers used were acid washed bottles delivered to IGT by Environment Canada personnel.

The samples were subsequently shipped to L. B. Pearson International Airport in coolers via air express on January 25, 1984. The samples were expedited through Customs and delivered to ORF on January 26, 1984.

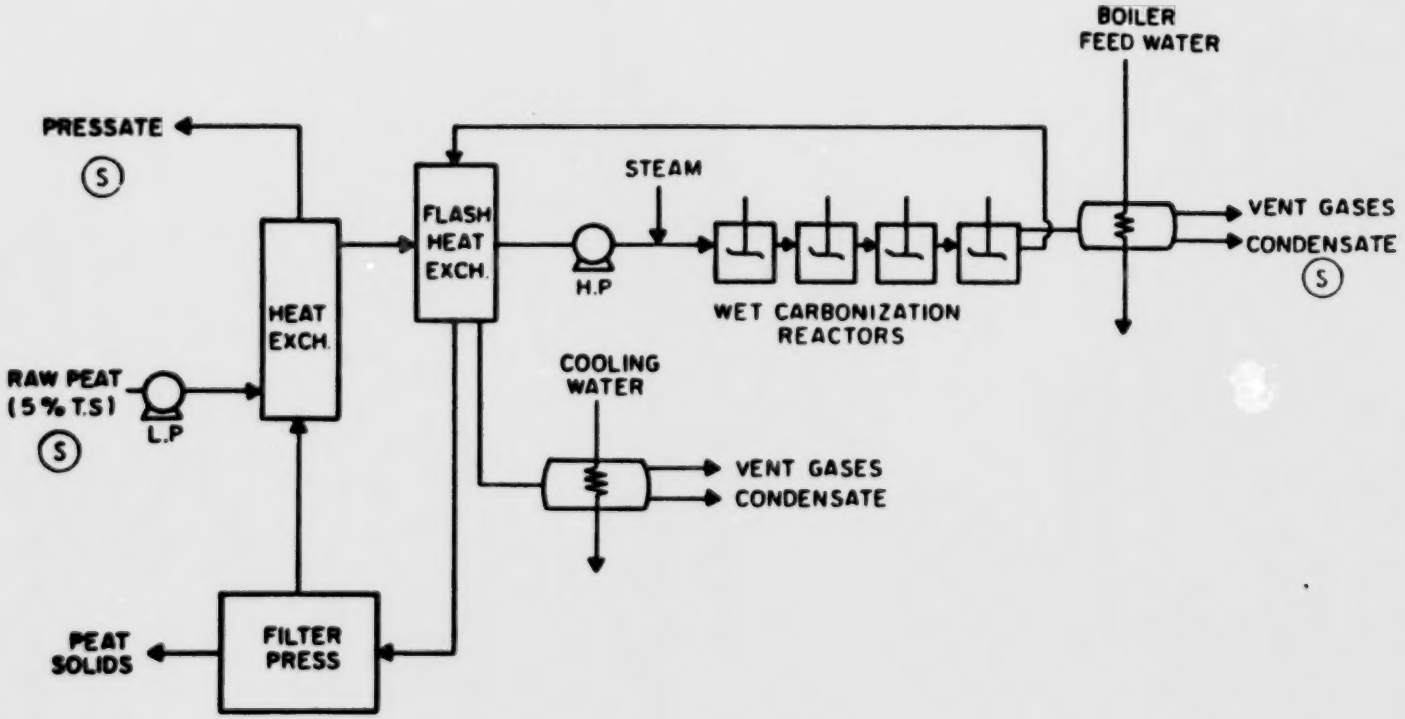


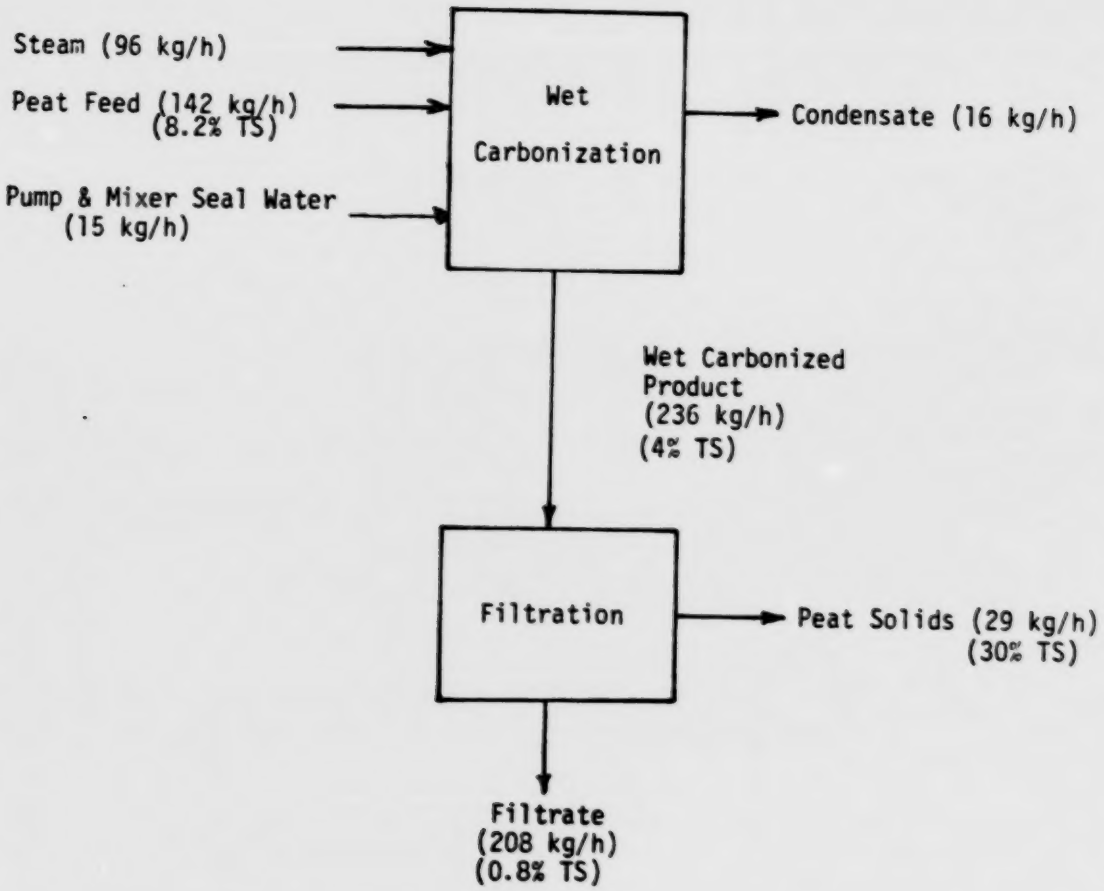
FIGURE 2.2-1

IGT - WET CARBONIZATION / DEWATERING OF PEAT.

(S) - Sample Point

FIGURE 2.2-2

IGT - Wet Carbonization Process
Overall Mass Balance[a]



(a) Not corrected for dilution of input to filtration with approximately one third raw peat feed

2.3 Université de Sherbrooke - Low-Severity Peat Dewatering Process

The low-severity peat dewatering technology has been under development at the Université de Sherbrooke. The process has the principal features of relatively low temperature and residence time in comparison with conventional wet carbonization processes. The low-severity technique employs both mechanical and thermal action to alter the hydrophilic nature of peat.

Figure 2.3-1 shows a schematic of the low-severity peat dewatering technology. Raw (wet mined) peat is preheated (in a heat exchanger). The peat is further heated by steam injection to approximately 190°C in a mixing vessel. The peat process stream is discharged through a nozzle before entering a plug flow reactor in which it is held for a residence time of a few minutes. Discharge from the plug flow reactor is flashed (with the vapour stream used for direct injection) and the process peat slurry heat exchanged with the raw peat. The cooled processed peat is subsequently dewatered to yield the peat fuel product and filtrate.

Processing Conditions

Peat processing trials were conducted at the Université de Sherbrooke in the facilities of the Faculté des sciences appliquées under the direction of Dr. E. Shornet. Several batch trials were conducted using 300 g lots of peat slurry prepared from the same high humified peat which was employed at the McGill University and the Ontario Research Foundation for this programme. The experimental procedure was described in correspondence from Sylvain Leger, graduate student.

The raw peat (supplied by ORF) was diluted with distilled water (30% by weight of the raw peat) and flash-mixed with a food processor. The resultant peat slurry (300 g) was charged into a small agitated vessel maintained at 135°C. The vessel was pressurized with nitrogen to approximately 15 MPa. After a two-minute retention time, the peat slurry was discharged through a shearing device (nozzle) to a second batch vessel. (The discharge vessel was previously charged with 50 mL of water and preheated to 170°C to avoid a large temperature drop in the second reactor). The peat slurry (and added water) were brought to 170°C (within two minutes) and then maintained at 170°C for a further two minutes before the reactor was quenched.

The cooled processed peat slurry was subsequently filtered (with a Buchner filtration kit using a Whatman No. 1 filter paper). This differs from the other thermal treatment processes which dewatered the peat product in larger quantities and with less efficient solids retention.

The overall mass balance for the process is presented in Figure 2.3-2.

Sample Handling

Filtrate samples (from each batch run) were stored immediately after filtration in a freezer. Samples of raw peat slurry (as fed to the batch reactors), oven dried peat product and filtrate (a composite of filtrates collected from each run) were delivered by overnight courier service from Sherbrooke to the Ontario Research Foundation.

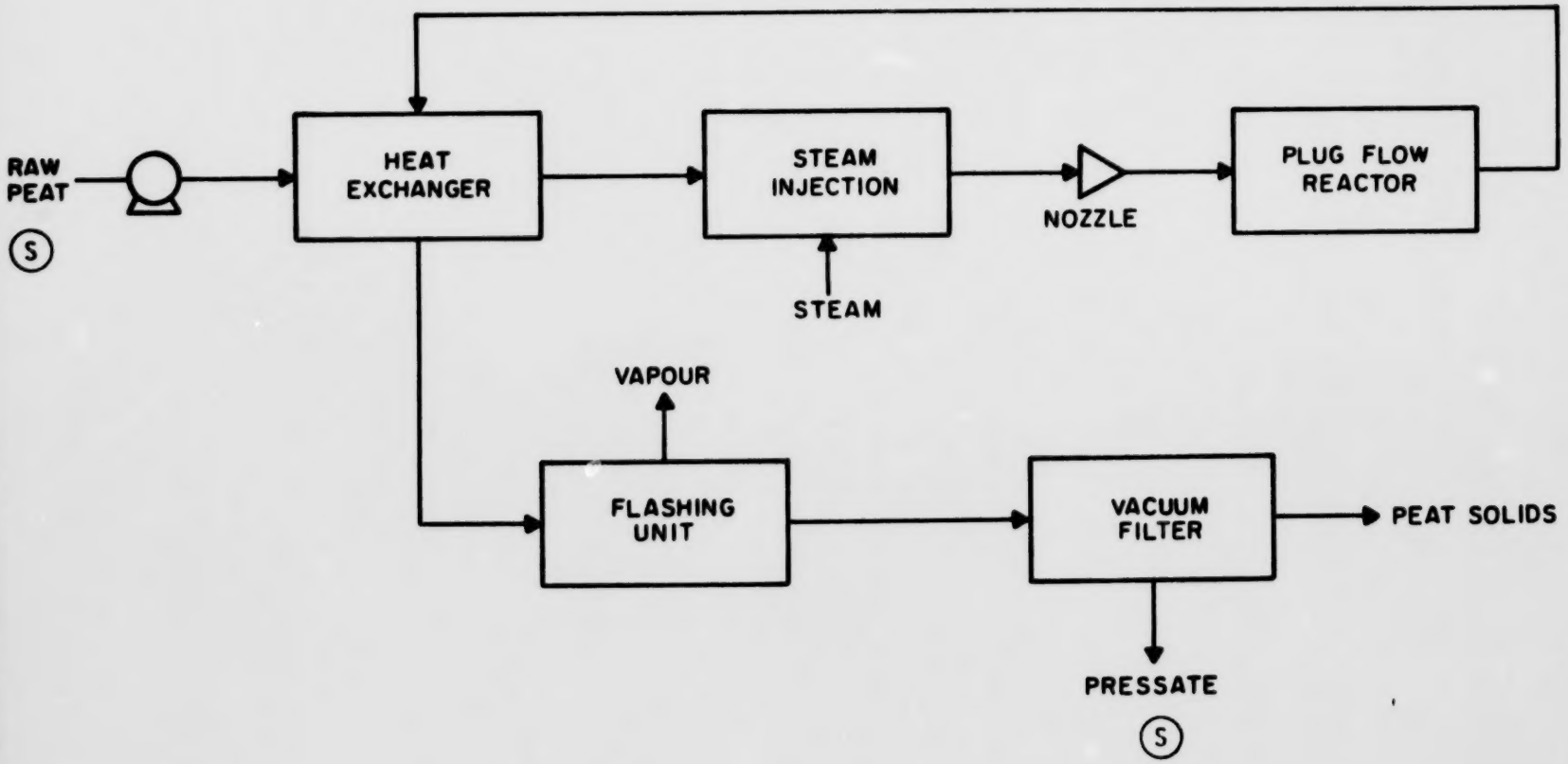


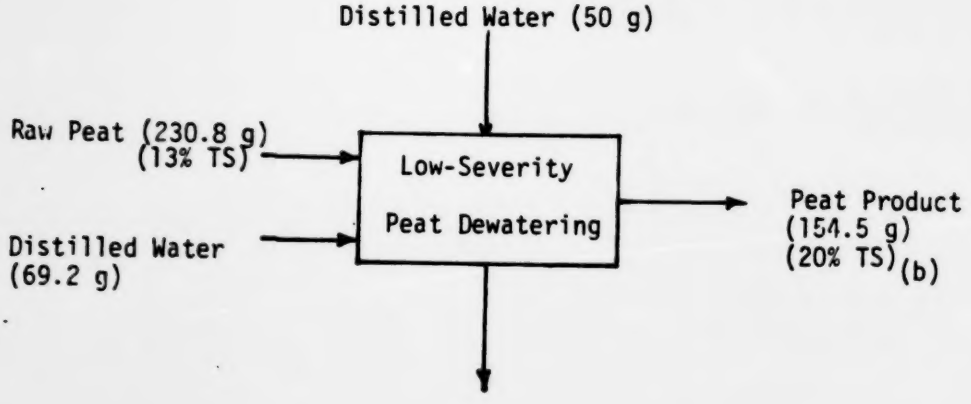
FIGURE 2.3-1

UNIVERSITE de SHERBROOKE - LOW SEVERITY PROCESS FOR PEAT DEWATERING.

(Figure supplied by Dr. E. Shornet, Université de Sherbrooke)

FIGURE 2.3-2

Université de Sherbrooke - Low-Severity Peat Dewatering Process
Overall Mass Balance[a]



(a) Approximate
(b) Assumed

2.4 McGill University - Peat Dewatering with Microbial Products

Process Background

Recent work conducted at the McGill University in Montreal has been directed towards the study of biological products, such as surfactants, emulsifiers, enzymes and charged polymers, as potential aids in the dewatering of peat. Three types of biological products (enzyme, biosurfactant, and charged polymer) have been identified as enhancing peat dewatering. They have been isolated from fermentation products. (Peat has been reported as the source of fermentation substrate).

Figure 2.4-1 shows a schematic representation of an integrated process for the production of fuel grade peat which incorporates the microbially derived dewatering aid.

Preliminary bench scale trials have produced mechanically dewatered peat of less than 60% moisture content using a charged polymer as a dewatering agent. Further work is being conducted to optimize the process (Cooper, Pillon and Mulligan, 1984).

Processing Conditions

The dewatering trials, using a microbial product as an aid, were conducted at McGill University, Montreal, Quebec. The work was conducted under the supervision of Dr. David Cooper of the Department of Chemical Engineering. The trials were conducted on January 16, 1984. The work employed a peat sample (1 litre) supplied by the Ontario Research Foundation. This peat was the same high humified peat employed in the ORF wet oxidation trials.

The work entailed the following sequence of events:

(i) The active ingredient is added to a sample of peat (approximately 25 g wet weight) and the mixture mechanically stirred for 5 minutes.
(ii) The sample is transferred to a hydraulic press and pressed for 2.5 minutes at 1.95 MPa.
(iii) The samples of pressed cake and pressate are separately collected.

A total of 0.32 g of active ingredient (charged polymer) was employed over 10 runs.

Figure 2.4-2 shows the overall mass balance reported for the trial.

Sample Handling

Pressates from each of ten runs (totalling approximately 100 mL) were collected into a single 1 litre glass bottle for delivery to Ontario Research Foundation. The sample was shipped on January 16, 1984, in a styrofoam cooler complete with freezer packs, and was delivered to ORF for analysis on January 17, 1984.

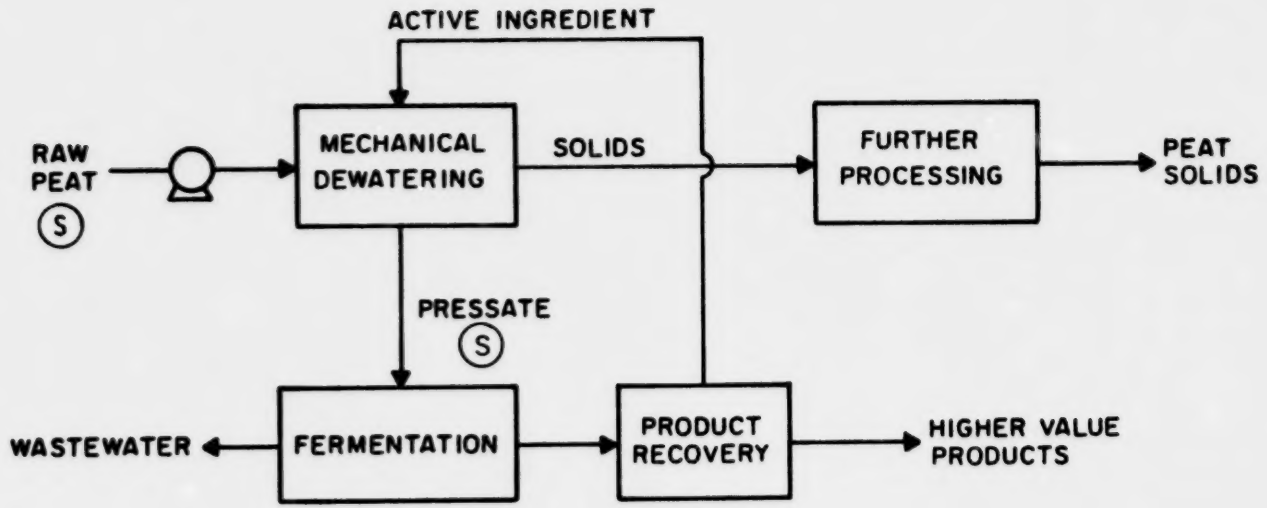


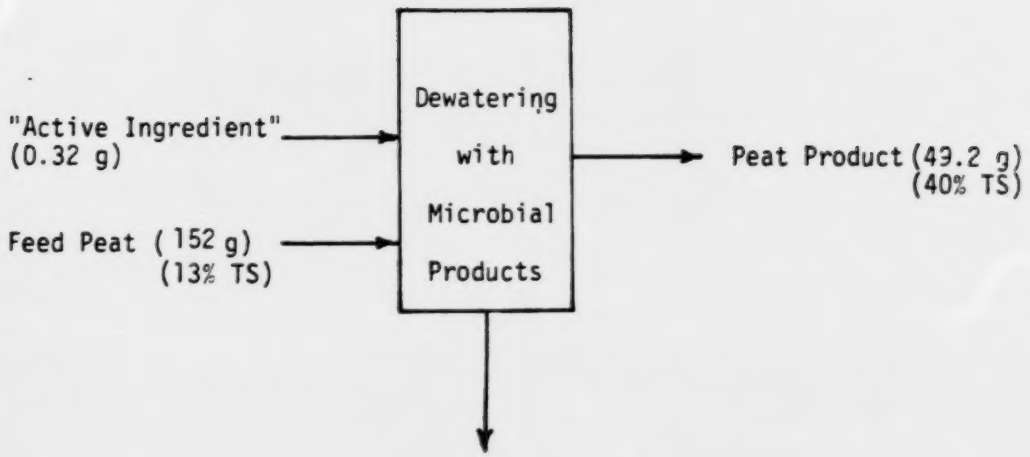
FIGURE 2.4-1

Mc GILL-PEAT DEWATERING WITH MICROBIAL PRODUCTS

(S) - Sample Point

FIGURE 2.4-2

McGill University - Peat Dewatering with Microbial Products
Overall Mass Balance



2.5 CRIQ Rotary Press

Process Background

The Centre de Recherche Industrielle du Québec has recently developed a novel press which has been employed for the dewatering of peat. The press incorporates two concentric wheels. The inner wheel slowly rotates, while the outer wheel is fixed. Peat is fed to the press at one point in the periphery of the wheel via a screw mechanism. The peat travels around the wheel, through the annular space, bounded by the inner and outer wheels and screens positioned on either side. High shear forces are developed within the peat as it travels through the annular space to the point of discharge. Water expressed due to the resultant high pressures drains from screens on the wheel's sides, to be collected in and discharged from a pan positioned beneath the press.

The process is shown schematically in Figure 2.5-1.

Processing Conditions

Peat dewatering trials were conducted at the CRIQ, located in Quebec City. The work was performed on February 15, 1984, with the assistance of Mr. Guy Coulombe and Mr. Dan Michaud of the Environmental Protection Service, Environment Canada, and under the direction of Adrian Barbulescu.

The trials were conducted using a fibrous peat obtained from the Champlain peat bog, located near Levis, Québec. This peat was employed after initial attempts with a more highly humified peat supplied by the National Research Council proved unsuccessful with the press as then equipped.

The press employed for the trial was a 17.5 cm diameter press, with a 1.25 x 3 cm annular sectional area. The side screens were of a 35 mesh. Pressures ranging between 290-360 psi were developed at the peat discharge point over the 20-minute duration of the trial. The rotational speed was maintained at 0.25 revolutions per minute.

The overall mass balance reported for the trial is shown in Figure 2.5-2.

Sample Handling

Representative samples of raw peat, peat feed solution, and filtrate were placed in sample containers (complete with preservatives - see Appendix 5) which were provided by ORF. The samples were put in coolers and packed in snow on the day of the trial. The coolers were shipped via express bus on the following day. The preserved and chilled samples were divided into two lots (at ORF) for subsequent delivery of one lot to the Wastewater Technology Centre and analysis of the other at ORF as part of a quality control program.

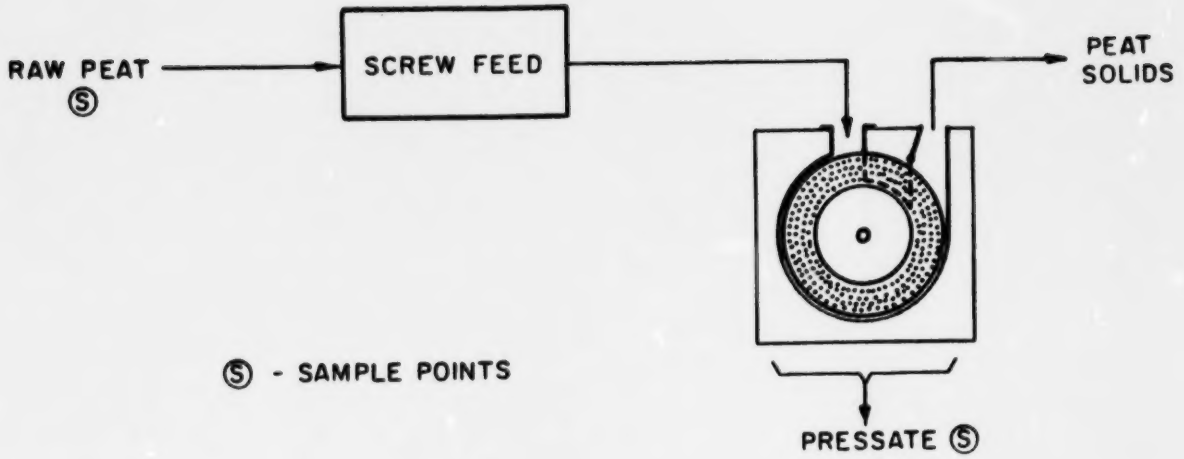
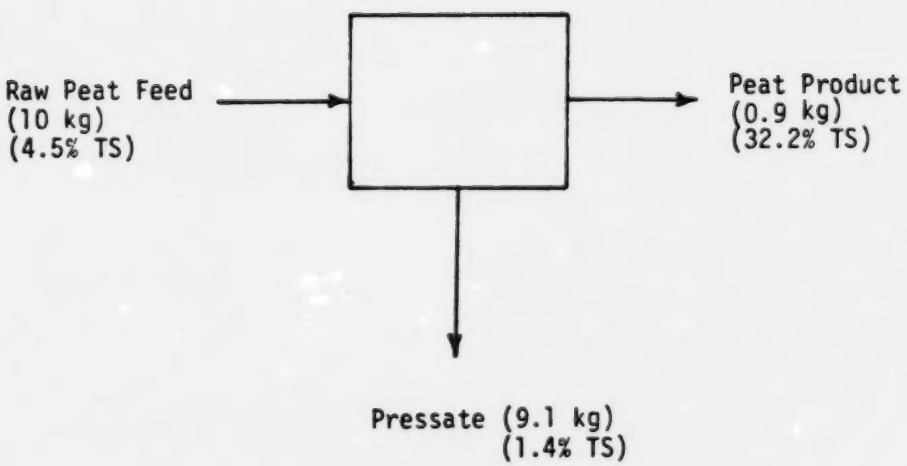


Fig. 2.5-1 CRIQ - ROTARY PRESS FOR PEAT DEWATERING.

DRAWING ADAPTED FROM KAMYR, INC.

FIGURE 2.5-2

CRIQ Rotary Press
Overall Mass Balance



3. ANALYTICAL PROCEDURES

3.1 General Chemical Procedures

3.1.1 General Chemical Procedures for Filtrate/Pressates & Vapour Phases

References: Standard Methods for the Examination of Water and Wastewater, APHA-AWWA-WPCF, 15th edition, 1980.

Peat Testing Manual, National Research Council, Canada, Technical Memorandum No. 125, May 1979.

American Society for Testing Materials, Annual Book of Standards. Part 31, 1982.

Preservation Techniques

Group 1 - collected in polyethylene bottle (rinsed three times with tap water, once with chromic acid, three times with distilled water, once with 1+1 HNO_3, and three times with distilled water).

- contains no preservatives
- filled to capacity
- kept at $4^{o}C$

Group 2 - collected in glass bottle (rinsed three times with tap water, once with chromic acid, three times with tap water and three times with distilled water).

- 1 mL of conc. H_2SO_4 added after 1000 mL sample is in bottle.
- cap with foil or teflon lined cap
- kept at $4^{o}C$

General Chemical Analytical Procedures are outlined in Table 3.1-1

3.1.2 General Chemical - Analytical Procedures Used on Raw Peats and Feed Slurries.

Total Solids and Volatile Solids

SM 209E as for liquids on a weight/weight basis.

Chemical Oxygen Demand

Two to three large aliquots were homogenized using a tissue grinder or food processor. After combining and homogenizing these aliquots, at least six replicate samples (approximately 50 - 200 mg) were weighed to 0.1 mg accuracy and transferred to COD tubes. The samples were refluxed for two hours at 150°C in a convection oven with $K_2Cr_2O_7$ (range 100 - 1000 ppm COD) and 50% H_2SO_4 solution. Ag_2SO_4 was added as a catalyst and $HgSO_4$ added to prevent Cl^- interference. Increase in Cr III was measured spectrophotometrically at 600 nm.

Total Carbon and Total Organic Carbon

Triplicate, approximately 2 g, aliquots from a sample homogenized as for COD were slurried into 200 mL volumetric flasks and the solids further dispersed using an ultrasonic probe (Branson Model S-125 Sonifier). Total carbon and TOC were determined as for liquid samples except an average value from at least ten injections was used.

pH

pH was determined on 3 g air-dried peat in 50 mL of distilled water, as described in the NRC Peat Testing Manual (3.1.1.).

Total Acidity

SM 402(4c) determined on a weighed aliquot of wet peat in de-aerated water (sparged with N_2 for approximately 1/2 hour).

Oil and Grease

SM 503D. 20g of wet peat was acidified to pH less than 2 with 1+1 HCl and dried by mixing with anhydrous magnesium sulphate. The resulting mixture was ground using a mortar and pestle and transferred to an extraction thimble. The thimble was transferred to a soxhlet apparatus and extracted with 1,1,2,-trichloro-1,2,2,-trifluoroethane (freon) at approximately 20 cycles per hour for 4 hours. The freon was evaporated in a fume hood at approximately 23^{o}C and "oil and grease" measured gravimetrically.

Total Volatile Acids

SM 504B. A weighed aliquot of wet peat was analyzed as for liquid samples.

Phenolics

SM 510A. A weighed sample of wet peat was distilled from $CuSO_4/H_3PO_4$ solution buffered to approximately pH 4. The distillate was analyzed by the Ontario MOE method as for liquid samples.

Ammonia

SM 417 A & D. A weighed amount of wet peat was analyzed as for liquid samples.

Total Kjeldahl Nitrogen

ASTM D3590-77, a weighed aliquot of wet peat was analyzed as for liquid samples.

Total Phosphorus

Analyzed by D.C. Plasma Emission Spectrophotometry along with "metal" scan or a weighed aliquot of wet peat was analyzed by persulphate digestion and colorimetric determination of PO_4. The methods were found to be equivalent on five samples analyzed by both procedures.

Total Sulphur

Analyzed by Leco High Temperature Sulphur analyzer after drying wet peat samples. Results were calculated on a wet weight basis to be consistent with other data.

3.1.3 General Chemical Analysis - Quality Control

Precision Data

The precision of the several general chemical analysis methods are summarized in Table 3.1-2. They were based on difference from average in replicate determinations. For feed and raw peats, all samples were analyzed for each parameter at least in duplicate. Filtrates and pressates from all Wetox samples were analyzed for all

parameters at least in duplicate. Vapour phase samples (five ORF wet oxidation and IGT wet carbonization condensates) were analyzed for all parameters, except SS, in duplicate.

Accuracy

Solids - not applicable

Chemical Oxygen Demand - not applicable

Total Carbon and Total Organic Carbon - When measured against mixed potassium acid phthalate, sodium carbonate and sodium bicarbonate reference material, recoveries are assumed 100% for inorganic carbon. Recoveries on 65 mg/L ethanol, 100 mg/L acetic acid and 20 mg/L formic acid were 99.85%, 100.0% and 99.88% respectively.

pH - electrode used, Orion Model 91-05, and meter used, Orion Model 601A, had a relative accuracy of $\pm$ 0.02 pH and $\pm$ 0.01 pH respectively.

Acidity - not applicable due to high organic acid content of most samples.

Total Volatile Acids - Recoveries on 1000 mg/L acetic acid and 630 mg/L formic acid were 99.2% and 88.7% respectively.

Colour - not applicable

Phenolics:

- Raw and Feed Peats - recoveries on samples spiked at the 10 and 200 µg/L of phenol level through both the manual distillation and automatic distillation procedure were 108% and 88% respectively.

- Filtrates and Pressates - recoveries on diluted samples spiked at the 10 and 20 µg/L level with phenol were 108% and 96.5% respectively.

- Vapour Condensates - recoveries on diluted samples spiked at the 5 and 20 µg/L level with phenol were 98.6% and 104% respectively.

Various recoveries of other "Phenolic Compounds"

a) pure phenol by manual distillation recovered 96%.
b) m-cresol by Technicon method recovered 59.4%
c) mixed standard from "acid extractable - priority pollutant" determination - using Technicon method - recovered 14.5% of available "phenol".

Ammonia - recoveries of spiked samples at the 50 and 200 mg/L N level were 109% and 99% respectively.

Kjeldahl Nitrogen - recovery of urea nitrogen at the 500 mg/L N level was 93%.

Total Phosphorus - not available.

Sulphate and Nitrates - no data available.

Total Sulphur - not available.

Total Sulphide - (on previous work done at ORF), samples of waste from a steel mill spiked at the 5 and 30 mg/L sulphide level recovered 72% and 85% respectively.

5-Day Biochemical Oxygen Demand

All samples were analyzed at least in duplicate for BOD. Analysis was commenced on March 8, 1984, when sample age ranged from two weeks to three months and, as such, the values must be taken as minimum BOD. CODs performed on the samples immediately prior to setting up the BOD test showed on average reduction of 9% COD for filtrates and pressates since first analyzed.

Samples of vapour condensates were filtered through 1.5 μ retention glass fibre discs prior to BOD determinations. Large amounts of waxy type material had deposited on the sides of the Nalgene bottles on storage at $4^{o}C$ so only soluble BOD was determined on the vapour phase samples. Soluble CODs (SCODs) performed on the samples immediately before BOD analysis showed an average reduction of 27% from the original total COD value.

Determinations of glucose-glutamic acid reference material in our laboratory routinely recovers 98% of the calculated BOD using settled municipal raw sewage from mixed industrial and domestic sources as a "seed".

TABLE 3.1-1 - General Chemical Analytical Procedures

PARAMETER	REFERENCE	DESCRIPTION	PRESERVATION & HOLDING TIME
Acidity	SM. No. 402,4c ASTM No. D1067-77A	Potentiometric titration to pH 3.7 and 8.3	immediate analysis
Ammonia	SM No. 417, A&D ASTM No. D1426-79A	Steam distillation from borate buffered, pH 9.5, solution into boric acid. Titrimetric determination of ammonia in distillate.	Group 2 24 hours
Biochemical Oxygen Demand (BOD)	SM 507 & 421 A & B	Dilution of sample with nutrient and micro-organism enriched aerated water. Dissolved oxygen measured initially and after 5 days light excluded incubation at 20°C by the azide modification to Winkler iodimetric titration.	immediate analysis N.B. See "Accuracy Section"
Chemical Oxygen Demand (COD)	Water Pollution Control, May/June 1978, pp.25-29, Knechtel, J. Ross.	Sealed tube dichromate reflux; modified to colorimetric	Group 2 24 hours
Carbon, Total	ASTMD2579-78A	Combustion-infrared by direct injection into total carbon channel of Beckman Model 915A Carbon Analyzer	Group 1 24 hours
Carbon, Organic (TOC)	SM 505 ASTMD2579-78A	Combustion-infrared after removal of inorganic carbon by acidification and sparging with nitrogen.	Group 2 1 week
Chloride	SM 407C	Potentiometric titration, in acid solution, using a silver-silver sulphide electrode.	none
Colour, True	SM 204A	Filtration through 0.45u and visual comparison in nessler tubes against chloro-platinate standards.	Group 1 24 hours
Total Kjeldahl Nitrogen	SM 420B ASTMD3590-77	Microkjeldahl digestion and steam distillation followed titrimetric measurement of NH_3.	Group 2
Nitrate	-	After filtration through 0.45u , ion chromatography under standard conditions using standard columns.	Group 1 24 hours

PARAMETER	REFERENCE	DESCRIPTION	PRESERVATION & HOLDING TIME
Oil and Grease	SM 503A	Sequential extraction of acidified sample with 1,1,2-trichloro-1,2,2-trifluoroethane. Combined "freon" extracts evaporated at ~25°C and residue measured gravimetrically.	Group 2 1 week
pH	SM 402	Electrometric measurement	immediate analysis
Phenolic Compounds as Phenol	Ontario Ministry of the Environment "Determination of Phenolic Compounds, Method A", October 6, 1974.	Technicon automated distillation and 4-AAP colorimetric	5 mL of 5% v/v H_3PO_4/10% w/v $CuSO_4$ per 1000mL Immediate analysis.
Phosphorus, Total	SM 424 C & E	H_2SO_4 - persulphate digestion, and colorimetric analysis of neutralized aliquot using stannous chloride ammonium molybdate.	Group 2 1 month
Sulphate	-	Ion Chromatography after filtration through 0.45µ	none
Sulphide	10th Ed. SM for evolution SM 427 D for titration	Sulphide is evolved from the sample by sparging an acidified aliquot with nitrogen and trapping H_2S in zinc acetate solution. Sulphide in absorbant is determined iodimetrically	"BOD" bottle (300 mL cap.) with 0.5 mL 2N zinc acetate added before sampling
Total Solids	SM 209A	Evaporation at 105°C and gravimetric measurement	immediate analysis.
Volatile Solids	SM 209E	Ignition at 550°C of dried residue from Total Solids determination	immediate analysis
Suspended Solids	SM 209D	Filtration through pre-fired tared glass fiber discs (~1.5µ retention), drying at 105°C and gravimetric measurement of non-filtrable residue.	immediate analysis

PARAMETER	REFERENCE	DESCRIPTION	PRESERVATION & HOLDING TIME
Volatile Suspended Solids	SM 209D-E	Ignition at 550° of dry non-filtrable residue and gravimetric measurement.	immediate analysis
Total Volatile Organic Acids	SM 504B	Steam distillation from acidified sample followed by titration of distillate with standard NaOH solution to pH 8.3.	immediate analysis

TABLE 3.1-2 - Precision of General Chemical Analyses

Parameter	RELATIVE STANDARD DEVIATION		
	Raw & Feed Peats	Filtrates & Pressates	Vapour Condensates
Total Solids	±1.2%	±1.2%	±3.%
Volatile Solids	±2.	±1.5%	±3.%
Suspended Solids	*	±2.%	*
Volatile Sus. Solids	*	±3.%	*
COD	±4.%	±5.%	±10.%
TC	±6.%	±5.%	±4.%
TOC	±6.%	+2.%	±4.%
pH	±0.1 pH unit	±0.1 pH unit	±0.1 pH unit
Acidity	+5.%	±3.%	±6.%
Total Volatile Acids	±15.%	±8.%	±11.%
Colour	*	±8. Hazen units	±50.Hazen Units
Phenolic Compounds			
Manual	±7.%	*	*
Automatic	±1.3%	±1.3%	±3.%
Ammonia	±5.%	±2.%	±2.%
Total Kjeldahl Nitrogen	±4.%	+2.%	±3.%
Total Phosphorus persulphate digestion	*	±3.%	*
Sulphate	*	±4.%	±12.%
Total Sulphide	*	*	*
BOD	*	±1.3%	*
SBOD	*	*	±2.5%

* Not applicable

3.2. Metal Analytical Procedures

Fixing Techniques

Total Metals - Collected in polypropylene bottle (rinsed with tap water, soaked in 1+1 HNO_3, rinsed with deionized-distilled water, rinsed with high purity HNO_3, rinsed six times with high purity deionized distilled water) - 10 mL of concentrated high purity HNO_3 added per 1000 mL sample immediately after collecting.

- Mercury: Collected in glass bottles (cleaned as above) - 10 mL of concentrated HNO_3 and 5 mL of 10% w/v $K_2Cr_2O_7$ added per 1000 mL of sample.

- Dissolved Metals: An aliquot of sample was filtered through 0.45 µ membrane, as soon as possible, and fixed with 1 mL concentrated HNO_3 per 1000 mL of sample.

- Dissolved Mercury: An aliquot of sample was filtered through 0.45 µ membrane, as soon as possible, and fixed for mercury as above.

Analytical Techniques

Multi-element

- Raw and Feed Peats: duplicate weighed portions of sample were digested with nitric acid and diluted to volume. The resulting solution was analyzed by D.C. Plasma Emission Spectrophotometry (DCPES).

- Pressates and Filtrates: an aliquot of sample was digested with concentrated aqua regia and diluted to volume. The resulting solution was analyzed by DCPES.

o Arsenic and Antimony: the sample was digested with nitric acid and sulphuric acids to fumes of SO_3 and diluted to volume with 20% hydrochloric acid. The solution was analyzed by hydride generation atomic absorption spectrophotometry.

Mercury

• Raw and Feed Peats: the sample was digested with sulphuric, nitric and hydrochloric acids and potassium persulphate and potassium permanganate. The resulting solution was reduced with hydroxylamine hydrochloride. The solution was further reduced with stannous chloride immediately before analysis by cold vapour atomic absorption spectrophotometry (A.A.S.).

• Filtrates and Pressates: sample was digested with sulphuric and nitric acids and potassium persulphate and potassium permanganate. The digested solution was reduced with hydroxylamine hydrochloride and diluted to volume. The solution was further reduced with stannous chloride immediately before analysis by cold vapour A.A.S.

Quality Control - summary of all peat samples analyzed.

	Hg	As, Sb, Se	Others
Samples	13	12	13
Spiked Samples	-	3	2
Controls	-	13	-
Replicates	24	12	8
Reag. Blanks	25	24	16

Complete digestion of a raw peat sample with perchloric acid was done to verify leachability of metals by HNO_3 digestion.

3.3 Determination of Humic and Fulvic Acid Fractions

Background

A great deal of difficulty arises in trying to define the terms "humic acid(s) and fulvic acid(s)". For example, in his book, Peat - Industrial Chemistry And Technology, (Academic Press, 1980), Charles H. Fuchsman devotes Chapter 12, some 32 pages, in an attempt to define the problem. He comes to the conclusion (p. 136) that "humic acids" is a term without a precise operational meaning. Fuchsman further states (p.137):

> "It is thus clear that substances that may be included in one investigator's sample of humic acid may have been removed by prior treatment of the sample used by another investigator. Such substances include some materials which, in other schemes of analysis would be identified as carbohydrates or proteins".

Fuchsman continues:

> "The ambiguity does not end with a consideration of sample treatment prior to the alkali extraction of the humic acids. The nature of the alkali used and the severity of the treatment may affect not only solubility but also the extent to which hydrolysis and oxidation may run during solution".

Perhaps the best "definition" of humic acids is found on p. 136 of Fuschman's book where humic acids are defined as being that portion of a peat sample soluble in alkaline solution, which is reprecipitated upon acidification of the alkaline extract.

Similar difficulties are encountered in attempting to define fulvic acid(s). The best definition Fuchsman (p.160) obtains is that "fulvic acid(s) is a group of substances which is brought into solution along with the humic acids on treatment with aqueous alkali, but which is not reprecipitated on acidification".

Adopted Terminology

In the analytical procedure used at ORF, the following terminology has been adopted:

- Total humic and fulvic acid fraction - is that portion of the sample, which is soluble in 0.1 N NaOH or made soluble by addition of 50% NaOH solution to an aliquot of the sample to pH 13 after removal of other soluble organic compounds by weak mineral acid extraction.

- Fulvic acid fraction is defined as the soluble portion of the aqueous alkaline extract from total humic and fulvic acid determination obtained when the alkaline extract is acidified with concentrated hydrochloric acid to approximately pH 2.

- Humic acid fraction is the insoluble portion obtained by acidification of the alkaline extract with HCl, and is determined by difference.

Treatment Procedure for Raw and Feed Peats

The methodology used at ORF was essentially an adaptation of the analytical procedure outlined in the Peat Testing Manual, pp.132-134, published by the National Research Council, Canada, Associate Committee on Geotechnical Research as Technical Mémorandum No. 125, May, 1979.

On raw peat samples and feed samples, where there is a high solids content, the total solids content was determined. Sufficient sample was taken to provide approximately 500 mg of solids on a dry weight basis. This was placed in a polypropylene bottle with 50 mL of HCl-HF solution (5 mL conc. HCL and 5 mL 48% HF to 1 litre). The bottle

was shaken for 72 hrs, the mixture filtered, and the solids dried over P_2O_5 in a desiccator. The dried solids were weighed and the weight noted. The dried solids were transfered to a polypropylene bottle (50-100 cc capacity) and 20 mL of 0.1N NaOH added. The solution was sparged with N_2 for 1 minute and shaken on a reciprocating shaker for 24 hours.

Treatment Procedure for Pressates, Filtrates and Vapour Condensates

Where possible, using an estimate from known solids content, a volume of sample was taken to yield approximately 500 mg dry solids. The sample was dried at 103°C in a convection oven and solids quantitatively transferred to a 50 mL polypropylene bottle by scraping and rinsing with 50 mL of HCl-HF solution.

The solids in HCl-HF solution were extracted on a rotary extraction apparatus at 15 RPM for 72 hours and separated by vacuum through 1.5 μ glass fibre discs. The solids and filter were washed with three 50 mL aliquots of distilled water.

After drying of the solids in a convection oven at 103°C for one hour and cooling in a desiccator over P_2O_5, the filters and solids were transferred to a 50 mL P/P bottle and 20 mL of 0.1 N NaOH (sparged with N_2 for 30 mins) added. The solutions were blanketed with nitrogen, capped and extracted on a rotary extractor at 15 RPM for 24 hours.

Determination of Humic and Fulvic Acid Fractions

The contents of the extraction bottle were then transferred to a centrifuge tube and centrifuged to separate the soluble and insoluble portions. The extract was collected by decantation and the residue shaken with two to four 20 mL aliquots of distilled water, centrifuging and decanting between each washing. The washings were collected with the

extract and made to a known volume. A portion of the alkaline extract was taken and the total humic and fulvic acid carbon content determined using a Beckman Model 915A carbon analyzer (combustion/infrared), after dilution if necessary. Samples were done in duplicate where possible, with at least triplicate injections for each into the 915A analyzer.

The remainder of the alkaline extract was acidified with concentrated HCl to pH 2 or less and allowed to stand for 24 hours. The humic acids precipitated, and the mixture was centrifuged. The supernatant was analyzed for fulvic acid carbon content using the 915A carbon analyzer, after dilution if necessary. Duplicate samples were taken and at least three injections of each sample were made on the 915 analyzer. The humic acid carbon content was determined as the difference between the total humic plus fulvic acid carbon content and the fulvic acid carbon content.

Accuracy

Unavailable, as yet, because of lack of "reference" material for humic and fulvic acid fractions other than peat itself.

Precision

- Raw and Feed Peat - All samples were analyzed in duplicate and the two Wetox peats were analyzed in triplicate on an "as received" and "air-dried" basis. There was essentially no difference between the humic and fulvic acid fractions found when calculated on the wet weight basis ($\pm$ 4%).

The differences from the average of duplicate determinations ranged from ± 4.7 to 8.9% on the fulvic acid fraction and ± 0.5 to 2.1% on the humic acid fraction (calculated by difference). The determination of total humic and fulvic acid fractions was essentially as precise as a total carbon determination (± 4%).

- Filtrates and pressates - four samples were analyzed in duplicate and the variation from average ranged from ± 10 to 30% for fulvic acid and ± 10 to 25% for humic acid fractions (calculated by difference from the total humic and fulvic acid fractions).

- Vapour Condensates - all seven samples were analyzed in duplicate with variation from average of essentially 100% in all cases. The only safe statement that can be made about the vapour phases is that they all contained less than 100 ppm carbon from fulvic and humic acid fractions.

3.4 High Performance Liquid Chromatography (HPLC)

Prior to analysis, all samples were filtered through a 0.45 μ filter in order to remove particulates. Detection of sugars, uronic acids and organic acids was accomplished with the use of a refractive index detector at 16X attenuation. Detection of HMF and furfural was accomplished using a differential UV detector at 2 AuFs. A BIO-RAD HPX-87 ion exclusion chromatographic column, in conjunction with a 0.01N H_3PO_4 mobile phase (0.6 mL/min) was used to chromatograph the samples. All instrument outputs were received by a Spectra Physics SP4270 Integrator for recording and integration. The areas of peaks of interest were related to the areas and response factors of known standards for interpretation.

Resolution of xylose, mannose and galactose was not possible under the column and eluent conditions employed. Results were reported as xylose, but include all three sugars.

3.5 Inorganic and Organic Anions by Ion Chromatography

The following anions were identified and/or quantified using the "anion" system of a Dionex Model 16: in order of elution-phosphate, succinate and bromide, malonate and nitrate, maleate, tartrate, sulphate and oxalate.

Analysis was performed by direct injection of an aliquot, filtered through 0.45 μ membrane, into the anion system of a Dionex Model 16 Ion Chromatograph. Columns used were "normal" anion concentrator/ precolumn (HPIC-AG1), anion separator (HPIC-AS1) and anion suppressor. "Standard" anion eluent (3.0 m$\underline{M}$ $NaHCO_3$/2.4 m$\underline{M}$ Na_2CO_3) at normal flow (2.3 mL/min) was used with conductivity detection.

Fluoride and chloride could not be identified or quantified by this technique because of large amounts of interfering organic anions (specifically acetate and formate) eluting at the same retention time. Sulphate and oxalate were well resolved from interfering organic anions and were quantified by the method of external and internal standards. Nitrate eluted at the same retention time (R.T.) as malonate so the absence of nitrate was confirmed by the brucine-sulphuric acid colorimetric procedure. Succinate eluted at the same R.T. as bromide but the absence of bromide was confirmed by a Br^- ion specific electrode and a phenol red colorimetric procedure.

Organic Anions Using Ion Chromatography Exclusion (ICE)

The following organic anions were identified and/or quantified using the exclusion mode of a Dionex Model 16; in order of elution - glycolate, succinate, formate, acetate and propionate. One inorganic anion, carbonate, was also quantified using ICE.

Analysis was performed by direct injection of an aliquot, filtered through 0.45 μ membrane, and diluted if necessary, into the ICE system of a Dionex Model 16 Ion Chromatograph. Columns used were "normal" ICE separator and "normal" ICE suppressor. Attempts to use a special "low pK_a" separator immediately after the "normal" separator were unsuccessful . "Standard" ICE eluent (0.01 M HCl) at 0.78 mL/min was used with conductivity detection.

Although the strong inorganic anions were well separated from the organic anions, great difficulty was encountered using this technique to quantify the various organic anions present in the filtrates and vapour condensates. This was partially due to a loss of capacity in the ICE "normal" separator used and partially due to the large quantities of some organic anions being close to the same retention time as lower amounts of other organic anions (e.g. formate and acetate). It was found that succinate eluted immediately before formate and caused the acetate and formate peaks to be very poorly resolved.

Because of these matrix effects, standards were made up with the same amount of organic anions estimated to be in the sample (method of internal standards worsened the resolution) and quantities of organic anions calculated from these. The data for formate and acetate should, therefore, be classified as estimates only.

3.6 Microtox™ Bioassays

Principle of the Method

The Microtox™ acute toxicity bioassay method is a commercially available microbial bioassay system using a specialized strain of luminescent bacteria as the bioassay organism. This test functions on the basis that the metabolism of the luminescent bacteria is influenced by low levels of toxicants. Any alteration of metabolism affects the intensity of the organism's light output. By sensing these changes in light output, the presence and relative concentration of toxicants can be detected.

The method is rapid, sensitive and requires only a few millilitres of test sample. Results are usually expressed in terms of effective concentration (EC_x) causing a stated percent decrease in light output. Normally an EC_{50} value is used, i.e. the concentration causing a 50% decrease in light from base level. Minimum detectable concentrations are those causing about a one percent reduction in base level light levels (EC_1).

Method

The Microtox test was conducted using the Beckman Microtox bacterium and test reagents. Dilutions of the peat pressates, filtrates, and vapour phase condensates were added to suspensions of the bacterium and incubated for 5 minutes at $15^{o}C \pm 0.1^{o}C$ prior to measurement of the luminous activity in a Turner Designs Model 20 Photometer fitted with a Lauda/Brinkmann RM3 cooling bath for temperature control. The values obtained were compared with the base level luminous activity where the bacterial suspension is not exposed to the test material. The resulting numerical expression is referred to as the

percent normalized light level. Initially a screening test was performed for each material in order to find the range in which the EC_{50} value was located. Tests at four different concentrations plus the zero base level were then run in duplicate in this range and the EC_{50} value determined from a graphical plot of the data.

In addition to 5 minute EC_{50} values at 15°C, runs were made with 15 minutes' preincubation, i.e. 15 minute EC_{50} values at 15°C were also determined. Further tests on three occasions were conducted on samples which had been adjusted to pH 6.7 to see whether the acidity accounted for a major portion of the toxicity in the various samples.

3.7 Determination of Acid Extractable Priority Pollutants

Procedures

As the samples were received, the pH was adjusted to 2 with 5N H_2SO_4. Methylene chloride was added in a 1:10 ratio (H_2Cl_2: sample volume). The samples were stored at 4°C pending extraction.

Extraction Procedure

The sample volume was measured and transferred to a 4 L bottle. A magnetic stirring bar was placed in the bottle and the sample plus CH_2Cl_2 was stirred vigorously for 20 minutes.

The contents of the bottle were transferred to a separatory funnel and the layers allowed to separate. If the layers did not separate, centrifuging was used to effect separation. The CH_2Cl_2 layer was dried by filtering through Na_2SO_4 into a 500 mL round bottom flask. The aqueous layer was returned to the bottle and the extraction repeated twice. The final combined CH_2Cl_2 extract was concentrated to approximately 100 mL on the rotary film evaporator. The concentrated extract was transferred to a 100 mL flask and made up to the mark with CH_2Cl_2.

If further concentration was necessary, this was carried out on a Kuderna-Danish type concentrator, and finally to small volume (less than 10 mL) on a Kontes tube evaporator.

The extract/flasks were wrapped in aluminum foil, labelled and stored in a freezer prior to analysis.

The feed slurry samples were extracted in separatory funnels and centrifuged.

GC-FID Analysis

Aliquots (3 L) of the extracts were injected onto the GLC.

GLC Parameters

Instrument	:	Varian 3700 fitted with flame ionization detection.
Column	:	15 metres x 0.25 μ DB-5 on fused silica.
Column Temperature	:	40°C initial for 1 min then 10°C/min to 270°C.
Injection Temperature	:	270°C.
Detector Temperature	:	350°C
Flow Rates	:	Carrier Gas - Nitrogen 2 mL/min, 30 mL/min make-up Hydrogen 30 mL/min Air 300 mL/min
Injection Mode	:	Splitless - 3 μL injection 30 sec to vent
Instrument Sensitivity	:	10^{-11} x 10

Quantitation was achieved by integrating the peak areas obtained in the GC/FID profiles, with a Spectra-Physics 4000 data processor.

A procedure was set up using retention time matching and calibration factors. These were predetermined by running a standard mixture of the priority pollutant phenols. Using this procedure a quantitation of the peaks tentatively identified as priority pollutant phenols was achieved.

Recoveries for Spiked Samples

Recoveries from spiked samples were performed by adding known concentrations of the phenols to aliquots of selected samples.

Spiking Additions

The standard solution (1 mL) was solvent exchanged with acetone, concentrated to 1 mL in a Kontes tube concentrator, and subsequently rinsed with 5 mL acetone into an aliquot of the sample. The sample was well mixed and the extraction procedure was carried out as previously described.

The results of the recoveries from spiked samples are shown in Table 3.7-1.

Confirmation of Phenol Identification

Confirmation of the presence of the respective phenols in the sample extracts was achieved by analyzing the extracts on a GC/Mass Spectrometer operating in the selected ion mode (SIM).

Retention time data and the major peak in the spectrum of each phenol was acquired by running the standard in the scan data acquire mode.

SIM parameters were then set up using these data and the extracts were analyzed. Positive confirmation was assumed, if the selected ions and the corresponding retention times agreed with the standard data.

GC/MS Parameters

Instrument	:	Hewlett Packard Model 5992B
GC Parameters	:	15 m x 0.25 μ DB-5 fused silica
Column Temperature	:	40°C initial for 3 min., then 10°/min to 270°C.
Injector Temperature	:	250°C
Solvent Vent	:	1.5 min
Flow Rate	:	Helium 1 mL/min

MS Parameters, SIM Mode

Electron Multiplier Voltage	:	2800 volts
SIM Window Size	:	0.2 amu
Dwell Times	:	100 m sec.

The selected ions are shown in Table 3.7-2.

TABLE 3.7-1 - Recoveries from Spiked Samples

Compound	Spike (mg/L)	Combined % Recovery	VPC % Recovery	Feed % Recovery
Phenol	16.4	79.0	55.5	58.7
2-Nitrophenol	18.2	120.3	69.3	120.0
2,4-Dimethylphenol	19.4	93.6	40.3	106.5
2,4-Dichlorophenol	21.2	97.2	76.6	87.6
p-Chlorophenol	18.8	138.0	34.6	68.0
4-Chloro-3-methyl	20.8	98.3	-*	68.7
2,4,6-Trichlorophenol	18.2	102.2	69.8	68.5
2,4-Dinitrophenol	44.0	73.9	-*	84.9
4-Nitrophenol	18.2	34.1	-	-
2,3,4,5-Tetrachlorophenol	17.2	80.9	70.0	57.9
2-Methyl-4,6-dinitrophenol	41.5	68.7	72.5	60.5
Pentachlorophenol	47.5	68.1	61.7	59.7

* These control samples gave large interfering peaks at similar retention times to the standard compounds. This prevented the calculation of recovery data for these compounds.

TABLE 3.7-2 - Selected Ions

Compound	Selected Ion (amu)	Retention Time (min)
Phenol	94.10	6.10
2-Nitrophenol	139.00	8.60
2,4-Dimethylphenol	107.00	8.94
2,4-Dichlorophenol	161.85	9.18
p-Chlorophenol	127.95	9.82
4-Chloro-3-methyl	107.00	11.30
2,4,6-Trichlorophenol	197.87	12.06
2,4-Dinitrophenol	184.00	14.30
4-Nitrophenol	139.00	14.70
2,3,4,5-Tetrachlorophenol	231.85	14.80
2-Methyl-4,6-dinitrophenol	198.05	15.60
Pentachlorophenol	164.85	17.30

3.8 General Comments on Analytical Techniques

Wet chemical techniques from Standard Methods for water and wastewaters were found to be generally applicable to the peat samples and process effluents. Precision with peat derived materials for these procedures was equivalent to that experienced with water and sewage.

Condensate samples required special precautions to prevent separation of waxy materials. These samples were best analyzed fresh (before refrigeration - which caused solidification and resultant adhesion of waxy materials to sample containers).

Metals analysis proceeded much as expected. A straight nitric acid digestion technique was found to give adequate recovery when compared with a more rigorous perchloric acid digestion procedure.

The procedures for humic and fulvic acids indicated the appropriate trend with degree of humification for the peat feed materials. The method did not give reproducible results for the vapour phase condensates. The technique likely resulted in the reporting of artifacts as humic and fulvic acid fractions. Waxy materials probably were responsible for the indicated results. Filtrate and pressate samples analyzed for humic and fulvic acid fractions gave reasonable precision with the technique employed.

High pressure liquid chromatography (HPLC) resolution of certain sugars, viz. xylose, mannose, and galactose, was not possible under the conditions employed. (These sugars may be separately quantifiable using different column and/or solvent conditions.)

Ion chromatography, while found to be a useful technique, was difficult to use for the identification of organic acids without the use of supplementary methods. A large number of separate peaks were noted, requiring the use of conventional wet chemical methods to confirm the presence or absence of suspected species.

Analysis of peat samples for acid extractable priority pollutants revealed considerable variability in detection limits amongst sample types. Confirmation of GC/FID results by GC-MS was required for the peat waters. Several false positives were noted by the GC/FID technique alone.

Microbial bioassay by Microtox™ was found to be a useful approach. A comparison of EC_{50} results from Microtox with LC_{50} results from fish bioassay was made, and showed a very good agreement. (See Table 5.2-1 for comparison of toxicity results.)

Quality assurance of analytical results was accomplished through the Wastewater Technology Centre, Burlington, Ontario. Kenneth Conn of WTC was responsible for the quality asurance programme. Duplicates of the following samples were delivered to WTC.

ORF - Wetox (Run 2)	Feed
	Condensate
	Combined Filtrate Pressate
IGT - Wet Carbonization	Feed
	Condensate
	Filtrate
CRIQ	Feed
	Pressate

Samples of material from the other two processes were not available in quantities sufficient for the analyses involved in the programme.

Good general agreement was reported by the two laboratories.

4. RESULTS

4.1 ORF Wet Oxidation/Dewatering of Peat

Six trials were conducted using the pilot scale wet oxidation facilities of the Ontario Research Foundation. Table 4.1-1 shows the results of the analysis by wet chemical techniques of samples of the two peats (one highly humified and the second moderately humified) used in the trials, together with a sample of bog water. All three samples were obtained from the same bog site. The content of selected metals in samples of the two peats and bog water are shown in Table 4.1-2.

Table 4.1-3 summarizes the characteristics determined for the feed, condensate (from condensed wet oxidation vapour phase effluent), filtrate (from vacuum filtration of liquid phase effluent), and pressate expressed from the vacuum filtered cake. A comparison of the filtrate and pressate characteristics reveals relatively minor differences between the two for most parameters. The exception is total and volatile suspended solids, where the filtrate contains much less particulate (as would normally be expected). On the bases of these analytical results and the small volume of pressate produced in comparison to the volume of filtrate, the filtrate and pressate were combined in subsequent trials.

Tables 4.1-4 through 4.1-8 contain summaries of the results obtained for the wet chemical and Microtox™ analysis of feeds and effluents from the five further trials.

The results of analyses for acid extractable priority pollutants in effluents from wet oxidation/dewatering trials 1 through 6 are summarized in Tables 4.1-9(a) through 4.1-9(f) respectively. Recovery efficiencies for the various priority pollutant parameters obtained for spiked samples of peat feed slurry, condensate and combined filtrate and

pressate respectively are shown in Table 3.7-1. Acid extractable priority pollutants were determined for representative feed samples of highly humified peat feed (Run 1) and medium humified feed peat (Run 6).

Table 4.1-10 summarizes the concentrations of selected metals in filtered and unfiltered samples of pressate and filtrate from Run 1 (demonstrating the relatively minor contribution of particulate matter to metal content) and unfiltered samples of feed and combined filtrate and pressate from Run 2.

Table 4.1-11 summarizes the levels of ionic species determined by ion chromatograph for combined filtrate and pressate and condensate samples from the second run and for combined filtrate and pressate from the sixth run. The earlier trial employed highly humified peat and the latter trial medium humified peat.

Table 4.1-12 shows the results of the high pressure liquid chromatographic characterization of sugars and related partial degradation compounds (organic acids and furfurals) from samples of condensate and filtrate obtained during wet oxidation trials Nos. 1 and 6.

TABLE 4.1-1
ORF-WET OXIDATION FEED MATERIAL
WET CHEMICAL AND MICROTOX RESULTS

		HIGH H PEAT	MEDIUM H PEAT	BOG WATER
TOTAL SOLIDS	mg/L	82800	66000	266
TOTAL VOLATILE SOLIDS	%	82.97	83	97.74
SUSPENDED SOLIDS	mg/L			2
VOLATILE SUSPENDED SOLIDS	mg/L			2
CHEMICAL OXYGEN DEMAND	mg/L	155000	105800	64
TOTAL ORGANIC CARBON	mg/L	46800	28300	20
TOTAL CARBON	mg/L	49000	30000	
pH		4.65	4.35	
ACIDITY, pH3.7	mg CaCO3/L	0	0	
, pH8.3	mg CaCO3/L	1890	2200	
TOTAL VOLATILE ACIDS	mg AcH/L	50	935	
TOTAL SULPHUR	mg/L	100	90	
PHENOLICS	mgPhenol/L	5.2	0.65	<0.001
AMMONIA	mg N/L	13	13	
TKN	mg N/L	1300	1340	<2
SULPHATE	mg/L			5
SULPHIDE	mg/L			
TOTAL PHOSPHORUS	mg/L	16	23	
FULVIC ACIDS	mg C/L	1400	800	
HUMIC ACIDS	mg C/L	16000	12000	
OIL & GREASE	mg/L	1580	1100	
MICROTOX, 5 min EC50	%			N.D.
MICROTOX, 15 min EC50	%			N.D.

TABLE 4.1-2
ORF-WET OXIDATION FEED MATERIALS
METAL ANALYSIS RESULTS

		HIGH HUMIFIED PEAT	MEDIUM HUMIFIED PEAT	BUG WATER
SODIUM	mg/L	20	37	8
POTASSIUM	mg/L	29	20	1.4
CALCIUM	mg/L	783	736	35
MAGNESIUM	mg/L	50	28	2.3
ALUMINIUM	mg/L	403	182	.3
BORON	mg/L	1.3	<0.2	.4
BERYLLIUM	mg/L	.04	.05	<0.003
PHOSPHORUS	mg/L	16	23	.44
COBALT	mg/L	.16	.29	<0.03
ZINC	mg/L	1.2	1.2	.04
MANGANESE	mg/L	4	5	.03
IRON	mg/L	612	521	1.7
CHROMIUM	mg/L	6.5	.9	<0.03
NICKEL	mg/L	1.4	.83	<0.03
COPPER	mg/L	2.3	.66	<0.03
MOLYBDENUM	mg/L	2	1.9	.07
LEAD	mg/L	.82	1.2	.05
BISMUTH	mg/L	<1	<1	<1
SILICON	mg/L	6.2	20	.1
CADMIUM	mg/L	.09	<0.2	<0.03
ARSENIC	mg/L	.34	.15	<0.001
MERCURY	mg/L	.02	.01	.0001
VANADIUM	mg/L	1.1	.74	<0.03
ANTIMONY	mg/L	.02	.02	<0.001

TABLE 4.1-3
ORF-WET OXIDATION RUN 1 (HIGH HUMIFIED PEAT, 220 C)
WET CHEMICAL AND MICROTOX RESULTS

		FEED	CONDENSATE	FILTRATE	PRESSATE
TOTAL SOLIDS	mg/L	58800	380	7670	9740
TOTAL VOLATILE SOLIDS	%	84.3	91	82	79.9
SUSPENDED SOLIDS	mg/L		234	385	3000
VOLATILE SUSPENDED SOLIDS	mg/L		234	320	2500
CHEMICAL OXYGEN DEMAND	mg/L	91300	12900	12600	15100
SOLUBLE COD	mg/L		7500		
TOTAL ORGANIC CARBON	mg/L		2800	4750	5900
SOLUBLE ORGANIC CARBON	mg/L		2100		
BOD5	mg/L		4940	5720	5430
pH			3.1	3.67	3.82
ACIDITY, pH3.7	mg CaCO3/L		350	50	0
, pH8.3	mg CaCO3/L		1750	3550	3300
TOTAL VOLATILE ACIDS	mg AcH/L		2000	3040	3100
COLOUR, TRUE	Hazen Units		100	4500	3000
PHENOLICS	mgPhenol/L	.715	350	23	19.9
AMMONIA	mg N/L	9	55	284	266
TKN	mg N/L	940	65	495	490
SULPHATE	mg/L		6	364	378
SULPHIDE	mg/L		<1	<1	<1
TOTAL PHOSPHORUS	mg/L		<.05	10	7.8
FULVIC ACIDS	mg C/L		<100	55	313
HUMIC ACIDS	mg C/L		<100	72	662
OIL & GREASE	mg/L		960	24	84
MICROTOX, 5 min EC50	%		.3	.23	.27
MICROTOX, 15 min EC50	%		.31	.25	.34

TABLE 4.1-4
ORF-WET OXIDATION RUN 2 (HIGH HUMIFIED PEAT, 200 C)
WET CHEMICAL AND MICROTOX RESULTS

		FEED	CONDENSATE	COMBINED
TOTAL SOLIDS	mg/L	65800	110	9520
TOTAL VOLATILE SOLIDS	%	81.2	81.8	83.1
SUSPENDED SOLIDS	mg/L		104	550
VOLATILE SUSPENDED SOLIDS	mg/L		104	470
CHEMICAL OXYGEN DEMAND	mg/L	95700	6980	13400
SOLUBLE COD	mg/L		5500	
TOTAL ORGANIC CARBON	mg/L		2400	4900
SOLUBLE ORGANIC CARBON	mg/L		1900	
BOD5	mg/L		3800	5890
pH			2.68	3.35
ACIDITY, pH3.7	mg CaCO3/L		650	700
, pH8.3	mg CaCO3/L		2100	5000
TOTAL VOLATILE ACIDS	mg AcH/L		2140	3090
COLOUR, TRUE	Hazen Units		60	8500
PHENOLICS	mgPhenol/L	.505	18.3	6.59
AMMONIA	mg N/L		14	307
TKN	mg N/L		27	536
SULPHATE	mg/L		7	290
SULPHIDE	mg/L		<1	<1
TOTAL PHOSPHORUS	mg/L		<.05	17
FULVIC ACIDS	mg C/L		<100	108
HUMIC ACIDS	mg C/L		<100	72
MICROTOX, 5 min EC50	%		.54	.37
MICROTOX, 15 min EC50	%		.45	.38

TABLE 4.1-5
ORF-WET OXIDATION RUN 3 (HIGH HUMIFIED PEAT, 180 C)
WET CHEMICAL AND MICROTOX RESULTS

		FEED	CONDENSATE	COMBINED
TOTAL SOLIDS	mg/L	60000	48	9920
TOTAL VOLATILE SOLIDS	%	86.3	50	84.8
SUSPENDED SOLIDS	mg/L		24	330
VOLATILE SUSPENDED SOLIDS	mg/L		24	280
CHEMICAL OXYGEN DEMAND	mg/L	93040	4800	12200
SOLUBLE COD	mg/L		3900	
TOTAL ORGANIC CARBON	mg/L		1700	5300
SOLUBLE ORGANIC CARBON	mg/L		1110	
BOD5	mg/L		2800	4610
pH			2.77	3.21
ACIDITY, pH3.7	mg CaCO3/L		488	680
, pH8.3	mg CaCO3/L		1600	5760
TOTAL VOLATILE ACIDS	mg AcH/L		1480	1990
COLOUR, TRUE	Hazen Units		40	10000
PHENOLICS	mgPhenol/L	.48	3.9	1.7
AMMONIA	mg N/L		7	190
TKN	mg N/L		8.4	410
SULPHATE	mg/L		10	470
SULPHIDE	mg/L		<1	<1
TOTAL PHOSPHORUS	mg/L		<.05	16
FULVIC ACIDS	mg C/L		<100	340
HUMIC ACIDS	mg C/L		<100	74
MICROTOX, 5 min EC50	%		.46	.4
MICROTOX, 15 min EC50	%		.34	.48

TABLE 4.1-6
ORF-WET OXIDATION RUN 4 (MODERATE HUMIFIED PEAT, 220 C)
WET CHEMICAL AND MICROTOX RESULTS

		FEED	CONDENSATE	COMBINED
TOTAL SOLIDS	mg/L	63000	314	8610
TOTAL VOLATILE SOLIDS	%	90	82.8	84.2
SUSPENDED SOLIDS	mg/L		192	64.5
VOLATILE SUSPENDED SOLIDS	mg/L		190	52
CHEMICAL OXYGEN DEMAND	mg/L	105400	8500	12400
SOLUBLE COD	mg/L		5600	
TOTAL ORGANIC CARBON	mg/L		2850	4900
SOLUBLE ORGANIC CARBON	mg/L		1760	
BOD5	mg/L		3850	6180
pH			2.97	3.4
ACIDITY, pH3.7	mg CaCO3/L		470	560
, pH8.3	mg CaCO3/L		1650	3800
TOTAL VOLATILE ACIDS	mg AcH/L		1950	2790
COLOUR, TRUE	Hazen Units		105	5500
PHENOLICS	mgPhenol/L	.65	55	22
AMMONIA	mg N/L	13	46	305
TKN	mg N/L		56	547
SULPHATE	mg/L		6	215
SULPHIDE	mg/L		<1	<1
TOTAL PHOSPHORUS	mg/L		<0.02	23
FULVIC ACIDS	mg C/L		<100	12
HUMIC ACIDS	mg C/L		<100	6
MICROTOX, 5 min EC50	%		.42	.35
MICROTOX, 15 min EC50	%		.36	.4

TABLE 4.1-7
ORF-WET OXIDATION RUN 5 (MODERATE HUMIFIED PEAT, 220 L)
WET CHEMICAL AND MICROTOX RESULTS

		FEED	CONDENSATE	COMBINED
TOTAL SOLIDS	mg/L	65000	182	9200
TOTAL VOLATILE SOLIDS	%	88.7	71.4	85.9
SUSPENDED SOLIDS	mg/L		168	211
VOLATILE SUSPENDED SOLIDS	mg/L		166	189
CHEMICAL OXYGEN DEMAND	mg/L	99200	6500	13600
SOLUBLE COD	mg/L		4920	
TOTAL ORGANIC CARBON	mg/L		1700	4950
SOLUBLE ORGANIC CARBON	mg/L		1290	
BOD5	mg/L		3500	5600
pH			2.8	3.18
ACIDITY, pH3.7	mg CaCO3/L		450	800
, pH8.3	mg CaCO3/L		1410	3840
TOTAL VOLATILE ACIDS	mg AcH/L		1950	2820
COLOUR, TRUE	Hazen Units		55	7000
PHENOLICS	mgPhenol/L	.03	20	6.5
AMMONIA	mg N/L		13	263
TKN	mg N/L		16	504
SULPHATE	mg/L		5	370
SULPHIDE	mg/L		<1	<1
TOTAL PHOSPHORUS	mg/L		.04	25
FULVIC ACIDS	mg C/L		<100	22
HUMIC ACIDS	mg C/L		<100	13
MICROTOX, 5 min EC50	%		.52	.41
MICROTOX, 15 min EC50	%		.44	.52

TABLE 4.1-8
ORF-WET OXIDATION RUN 6 (MODERATE HUMIFIED PEAT, 180 C)
WET CHEMICAL AND MICROTOX RESULTS

		FEED	CONDENSATE	COMBINED
TOTAL SOLIDS	mg/L	65500	1320	9096
TOTAL VOLATILE SOLIDS	%	92.1	89.4	88.4
SUSPENDED SOLIDS	mg/L		976	120
VOLATILE SUSPENDED SOLIDS	mg/L		952	110
CHEMICAL OXYGEN DEMAND	mg/L	101000	7200	11900
SOLUBLE COD	mg/L		7170	
TOTAL ORGANIC CARBON	mg/L		1850	4050
SOLUBLE ORGANIC CARBON	mg/L		1800	
BOD5	mg/L		3120	5050
pH			2.72	3.07
ACIDITY, pH3.7	mg CaCO3/L		360	710
, pH8.3	mg CaCO3/L		850	3370
TOTAL VOLATILE ACIDS	mg AcH/L		875	2250
COLOUR, TRUE	Hazen Units		110	6250
PHENOLICS	mgPhenol/L	09	3.85	1.35
AMMONIA	mg N/L		11	180
TKN	mg N/L		34	400
SULPHATE	mg/L		7	150
SULPHIDE	mg/L		<1	<1
TOTAL PHOSPHORUS	mg/L			25
FULVIC ACIDS	mg C/L		<100	21
HUMIC ACIDS	mg C/L		<100	22
MICROTOX, 5 min EC50	%		.16	.39
MICROTOX, 15 min EC50	%		.15	.4

TABLE 4.1-9(a) RUN 1 (HIGH HUMIFIED PEAT, 220 C)

	(UNITS)	FEED	CONDENSATE	FILTRATE	PRESSATE
PHENOL	mg/L	< .05	19.2	1.44	3.7
2-NITROPHENOL	mg/L	< .05	.22	.18	.2
2,4-DIMETHYLPHENOL	mg/L	< .05	< .05	< .05	< .05
2,4-DICHLOROPHENOL	mg/L	< .05	< .05	< .05	< .05
p-CHLOROPHENOL	mg/L	< .05	< .05	.24	< .05
4-CHLORO-m-CRESOL	mg/L	< .05	< .05	< .05	< .05
2,4,6-TRICHLOROPHENOL	mg/L	< .05	< .05	< .05	< .05
2,4-DINITROPHENOL	mg/L	< 1	< 1	< 1	< 1
4-NITROPHENOL	mg/L	< .05	< .05	< .05	< .05
2,3,4,5-TETRACHLOROPHENOL	mg/L	< .05	< .05	< .05	< .05
4,6-DINITRO-o-CRESOL	mg/L	< .06	< .06	< .06	< .06
PENTACHLOROPHENOL	mg/L	< 1	< 1	< 1	< 1

TABLE 4.1-9(b) RUN 2 (HIGH HUMIFIED PEAT, 200 C)

	(UNITS)	CONDENSATE	COMBINED
PHENOL	mg/L	57	.24
2-NITROPHENOL	mg/L	< .05	.15
2,4-DIMETHYLPHENOL	mg/L	< .05	< .05
2,4-DICHLOROPHENOL	mg/L	< .05	< .05
p-CHLOROPHENOL	mg/L	< .05	.27
4-CHLORO-m-CRESOL	mg/L	< .05	< .05
2,4,6-TRICHLOROPHENOL	mg/L	< .05	< .05
2,4-DINITROPHENOL	mg/L	< 1	< 1
4-NITROPHENOL	mg/L	< .05	< .05
2,3,4,5-TETRACHLOROPHENOL	mg/L	< .05	< .05
4,6-DINITRO-o-CRESOL	mg/L	< 1	.2
PENTACHLOROPHENOL	mg/L	< 1	< 1

TABLE 4.1-9(c) RUN 3 (HIGH HUMIFIED PEAT, 180 C)

	(UNITS)	CONDENSATE	COMBINED
PHENOL	mg/L	.5	.152
2-NITROPHENOL	mg/L	< .05	< .05
2,4-DIMETHYLPHENOL	mg/L	.27	< .05
2,4-DICHLOROPHENOL	mg/L	< .05	< .05
p-CHLOROPHENOL	mg/L	< .05	< .05
4-CHLORO-m-CRESOL	mg/L	< .05	< .05
2,4,6-TRICHLOROPHENOL	mg/L	< .05	< .05
2,4-DINITROPHENOL	mg/L	< 1	< 1
4-NITROPHENOL	mg/L	< .05	< .05
2,3,4,5-TETRACHLOROPHENOL	mg/L	< .05	< .05
4,6-DINITRO-o-CRESOL	mg/L	< 1	< 1
PENTACHLOROPHENOL	mg/L	< 1	< 1

TABLE 4 1-9(d) RUN 4 (MEDIUM HUMIFIED PEAT, 220 C)

	(UNITS)	CONDENSATE	COMBINED
PHENOL	mg/L	2.94	2.5
2-NITROPHENOL	mg/L	.115	< .05
2,4-DIMETHYLPHENOL	mg/L	.38	< .05
2,4-DICHLOROPHENOL	mg/L	< .05	< .05
p-CHLOROPHENOL	mg/L	.12	< .05
4-CHLORO-m-CRESOL	mg/L	< .05	< .05
2,4,6-TRICHLOROPHENOL	mg/L	< .05	< .05
2,4-DINITROPHENOL	mg/L	< 1	< 1
4-NITROPHENOL	mg/L	< .05	< .05
2,3,4,5-TETRACHLOROPHENOL	mg/L	< .05	< .05
4,6-DINITRO-o-CRESOL	mg/L	< 1	< 1
PENTACHLOROPHENOL	mg/L	< 1	< 1

TABLE 4 1-9(e) RUN 5 (MEDIUM HUMIFIED PEAT, 200 C)

	(UNITS)	CONDENSATE	COMBINED
PHENOL	mg/L	5.1	1.63
2-NITROPHENOL	mg/L	< .05	< .05
2,4-DIMETHYLPHENOL	mg/L	< .05	< .05
2,4-DICHLOROPHENOL	mg/L	< .05	< .05
p-CHLOROPHENOL	mg/L	.72	< .05
4-CHLORO-m-CRESOL	mg/L	< .05	< .05
2,4,6-TRICHLOROPHENOL	mg/L	< .05	< .05
2,4-DINITROPHENOL	mg/L	< 1	< 1
4-NITROPHENOL	mg/L	< .05	< .05
2,3,4,5-TETRACHLOROPHENOL	mg/L	< .05	< .05
4,6-DINITRO-o-CRESOL	mg/L	< .06	< .06
PENTACHLOROPHENOL	mg/L	< 1	< 1

TABLE 4 1-9(d) RUN 6 (MEDIUM HUMIFIED PEAT, 180 C)

	(UNITS)	FEED	CONDENSATE	COMBINED
PHENOL	mg/L	< .05	.87	.2
2-NITROPHENOL	mg/L	< .05	< .05	< .05
2,4-DIMETHYLPHENOL	mg/L	< .03	< .05	< .05
2,4-DICHLOROPHENOL	mg/L	< .03	< .05	< .05
p-CHLOROPHENOL	mg/L	< .03	< .05	< .05
4-CHLORO-m-CRESOL	mg/L	< .03	< .05	< .05
2,4,6-TRICHLOROPHENOL	mg/L	< .03	< .05	< .05
2,4-DINITROPHENOL	mg/L	< .06	< 1	< 1
4-NITROPHENOL	mg/L	< .03	< .05	< .05
2,3,4,5-TETRACHLOROPHENOL	mg/L	< .03	< .05	< .05
4,6-DINITRO-o-CRESOL	mg/L	< .06	< 1	< 1
PENTACHLOROPHENOL	mg/L	< .06	< 1	< 1

TABLE 4.1-10
ORF-WET OXIDATION RUNS 1&2
METAL ANALYSIS RESULTS

		RUN 1 (220 C)				RUN 2 (200 C)	
		FILTRATE		PRESSATE		FEED	COMBINED
		(TOTAL)	(FILTERED)	(TOTAL)	(FILTERED)		
SODIUM	mg/L	15	15	24	21	26	16
POTASSIUM	mg/L	7.7	7.1	11	8.7	20	7.6
CALCIUM	mg/L	388	389	461	420	621	404
MAGNESIUM	mg/L	19	19	24	21	35	20
ALUMINIUM	mg/L	57	54	88	54	291	150
BORON	mg/L	<0.5	<0.5	<0.5	<0.5	.29	<0.5
BERYLLIUM	mg/L	.004	.004	.008	.005	.04	.006
PHOSPHORUS	mg/L	9.4	9.3	8	4.6	16	15
COBALT	mg/L	.05	.05	.09	.08	.15	.07
ZINC	mg/L	.21	.25	.62	.5	1.2	.4
MANGANESE	mg/L	1.4	1.4	2.8	2.5	3.3	1.9
IRON	mg/L	87	82	187	121	442	104
CHROMIUM	mg/L	1	.08	5	.18	4.3	.52
NICKEL	mg/L	.05	.04	.28	.18	.39	.16
COPPER	mg/L	.05	.03	.39	.18	1.8	.11
MOLYBDENUM	mg/L	.3	.32	.49	.42	.89	.34
LEAD	mg/L	.15	.12	.39	.14	.75	.21
BISMUTH	mg/L	.08	.12	.12	.13	.35	.13
SILICON (a)	mg/L	1.6	3.3	2.2	3.2	15	<1
CADMIUM	mg/L	.06	.06	.06	.04	.07	.02
ARSENIC	mg/L	.051	.042	.049	.033	.092	.056
MERCURY	mg/L	.0002		.0009		.013	.0004
VANADIUM	mg/L	.14	.13	.22	.14	.9	.33
ANTIMONY	mg/L	.003	.002	.005	.003	.013	.017

(a) Results are approximate due to high blank values resulting from digestion of samples in borosilicate glassware

TABLE 4.1-11
URF-WET OXIDATION RUNS 2 & 6
ION CHRMATOGRAPHY RESULTS

			RUN 2 200 C (HIGH HUMIFIED PEAT) CONDENSATE	RUN 2 200 C (HIGH HUMIFIED PEAT) FILTRATE	RUN 6 180 C (MODERATE) FILTRATE
SUCCINATE		mg/L	<5	430	170
GLYCOLATE		mg/L	<10	900	<50
OXALATE		mg/L	<1	940	620
MALONATE		mg/L	<5	30	30
MALEATE		mg/L	<5	60	50
TARTRATE		mg/L	<5	<5	<5
FORMATE		mg/L	590	1400	690
ACETATE		mg/L	1100	1800	2000
PROPIONATE		mg/L	<5	<10	<10
TOTAL HALIDE	(a)	mg/L	<2	8	9
BROMIDE		mg/L	<1	<1	<1
NITRITE		mg N/L	<1	<1	<1
NITRATE		mg N/L	<1	<1	<1
ORTHO-PHOSPHATE		mg P/L	<1	8	15
SULPHATE		mg/L	7	290	150

(a) Determined by wet chemical technique

TABLE 4.1- 12
ORF-WET OXIDATION
HPLC ANALYSIS RESULTS

		RUN 1 CONDENSATE	RUN 1 FILTRATE	RUN 6 FILTRATE
GLUCURONIC ACID	mg/L	<10	288	423
GALACTURONIC ACID	mg/L	<10	735	800
ARABINOSE	mg/L	<10	<10	1200
RHAMNOSE	mg/L	<10	542	<10
XYLOSE	mg/L	288	<10	429
GLUCOSE	mg/L	62	206	339
FURFURAL	mg/L	38.1	6.7	147
HYDROXY METHYL FURFURAL	mg/L	27.2	38.5	4.53

4.2 IGT Wet Carbonization/Dewatering of Peat

A single pilot scale trial of wet carbonization and dewatering of peat was conducted at the Institute of Gas Technology in Chicago, Illinois. Table 4.2-1 summarizes the results of the analysis (by wet chemical techniques and Microtox™ assay) of samples of feed slurry, reactor condensate, and filtrate from product dewatering. The values reported for filtrate characteristics, in this and following Tables, are not corrected for the dilution present in the original sample caused by contamination of the wet carbonized product with raw peat feed slurry. The peat feed slurry and wet carbonized product were inadvertently mixed at approximately one part to two parts respectively by a short circuit in the process. Hence the concentration and loadings of chemical species added to the filtrate by heat treatment would be reduced by approximately one third by dilution with raw peat feed slurry.

The concentrations of acid extractable priority pollutants determined for the peat feed slurry, condensate and filtrate are summarized in Table 4.2-2.

Tables 4.2-3 and 4.2-4 show the results obtained for the analysis of peat feed slurry and filtrate for selected metals and for manomeric sugars and related compounds respectively.

The results of analysis of condensate and filtrate by ion chromatography are summarized in Table 4.2-5.

TABLE 4.2-1
IGT-WET CARBONIZATION WET CHEMICAL AND MICROTOX RESULTS

		FEED	CONDENSATE	FILTRATE
TOTAL SOLIDS	mg/L	47050	448	3980
TOTAL VOLATILE SOLIDS	%	84.7	82.6	84.2
SUSPENDED SOLIDS	mg/L		64	2280
VOLATILE SUSPENDED SOLIDS	mg/L		64	2140
CHEMICAL OXYGEN DEMAND	mg/L	68700	10300	6030
TOTAL CARBON	mg/L	27000	2000	1500
TOTAL ORGANIC CARBON	mg/L	23000	2000	1550
BOD5	mg/L		5230	1580
pH		5.15	6.94	5.09
ACIDITY, pH3.7	mg CaCO3/L	0	0	0
, pH8.3	mg CaCO3/L	290	270	127
TOTAL VOLATILE ACIDS	mg AcH/L	50	660	300
COLOUR, TRUE	Hazen Units		390	200
PHENOLICS	mg Phenol/L	.025	135	10
AMMONIA	mg N/L	5	370	56
TKN	mg N/L	1100	429	215
SULPHATE	mg/L		2	30
SULPHIDE	mg/L		<1	<1
TOTAL SULPHUR	mg/L	90		
TOTAL PHOSPHORUS	mg/L	9.66	.05	2.24
FULVIC ACIDS	mg C/L	830	<100	135
HUMIC ACIDS	mg C/L	5900	<100	95
OIL & GREASE	mg/L	100	438	34
MICROTOX, 5 min EC50	%		.2	9
MICROTOX, 15 min EC50	%		.18	8.9

TABLE 4.2-2

IGT-WET CARBONIZATION ACID EXTRACTABLE PRIORITY POLLUTANTS

		FEED	CONDENSATE	FILTRATE
PHENOL	mg/L	<.03	10.9	1.45
2-NITROPHENOL	mg/L	<.03	2.0	<.05
2,4-DIMETHYLPHENOL	mg/L	<.03	<.05	.2
p-CHLOROPHENOL	mg/L	<.03	<.05	<.05
4-CHLORO-m-CRESOL	mg/L	<.03	<.05	<.05
2,4,6-TRICHLOROPHENOL	mg/L	<.03	<.05	<.05
2,4-DINITROPHENOL	mg/L	<.06	<.10	<.10
4-NITROPHENOL	mg/L	<.03	<.05	<.05
2,3,4,5-TETRACHLOROPHENOL	mg/L	<.03	<.05	<.05
4,6-DINITRO-o-CRESOL	mg/L	<.06	<.10	<.10
PENTACHLOROPHENOL	mg/L	<.06	<.10	<.10

TABLE 4.2-3
IGT-WET CARBONIZATION METALS RESULTS

		FEED	FILTRATE
SODIUM	mg/L	38	14
POTASSIUM	mg/L	20	5.3
CALCIUM	mg/L	660	130
MAGNESIUM	mg/L	97	38
ALUMINIUM	mg/L	140	10
BORON	mg/L	<0.5	<0.05
BERYLLIUM	mg/L	02	<0.003
PHOSPHORUS	mg/L	25	2.6
COBALT	mg/L	.21	<0.03
ZINC	mg/L	.25	.46
MANGANESE	mg/L	11	1.7
IRON	mg/L	270	20
CHROMIUM	mg/L	.6	.17
NICKEL	mg/L	.22	.06
COPPER	mg/L	.27	.68
MOLYBDENUM	mg/L	1.9	.33
LEAD	mg/L	.64	.15
BISMUTH	mg/L	<1	<1
SILICON	mg/L	2.4	8.1
CADMIUM	mg/L	.03	<0.03
ARSENIC	mg/L	.16	.053
MERCURY	mg/L	.0025	.00054
VANADIUM	mg/L	.49	.06
ANTIMONY	mg/L	.006	.001

TABLE 4.2-4
IGT-WET CARBONIZATION HPLC RESULTS

		CONDENSATE	FILTRATE
GLUCURONIC ACID	mg/L	<10	<10
ACETATE	mg/L	<10	429
GALACTURONIC ACID	mg/L	382	<10
ARABINOSE	mg/L	<10	<10
RHAMNOSE	mg/L	<10	<10
XYLOSE	mg/L	<10	<10
GLUCOSE	mg/L	<10	<10
FURFURAL	mg/L	43.1	34.4
HYDROXY METHYL FURFURAL	mg/L	<.5	79.5

TABLE 4.2-5

IGT-WET CARBONIZATION ION CHROMATOGRAPHY RESULTS

		CONDENSATE	FILTRATE
SUCCINATE	mg/L	<5	19
GLYCOLATE	mg/L	5	220
OXYLALATE	mg/L	<1	2
MALONATE	mg/L	<5	<5
MALEATE	mg/L	<5	<5
TARTRATE	mg/L	<5	<5
FORMATE	mg/L	<1	98
ACETATE	mg/L	170	110
PROPIONATE	mg/L	50	<10
CHLORIDE (a)	mg/L	<1	8
BROMIDE	mg/L	<1	<1
NITRITE	mg N/L	<1	<1
NITRATE	mg N/L	<1	<1
ORTHO-PHOSPHATE	mg P/L	<1	<1

(a) Determined by wet chemical method.

4.3 Université de Sherbrooke - Low-Severity Peat Dewatering Process

A series of small scale batch trials were conducted at the Université de Sherbrooke employing their low severity peat dewatering process. The results obtained from the characterization of feed peat solution and filtrate are summarized in Table 4.3-1. (The batch apparatus did not provide for separate condensate collection). The Table contains results obtained by wet chemical analytical techniques and microbial toxicity and are not corrected for the addition of water in the process trials. Hence the reported concentrations are reduced by approximately one third through dilution with distilled water.

Table 4.3-2 indicates the concentrations of acid extractable priority pollutants determined in the sample of filtrate obtained from the process. Tables 4.3-3 and 4.3-4 summarize results of analysis for selected metal species and simple sugars and related compounds by high pressure liquid chromatography.

The levels of anions determined by ion exchange chromatography are shown in Table 4.3-5.

TABLE 4 3-1
UNIVERSITE de SHERBROOKE-LOW INTENSITY PROCESS
WET CHEMICAL AND MICROTOX RESULTS

		FILTRATE	FEED
TOTAL SOLIDS	mg/L	387	101000
TOTAL VOLATILE SOLIDS	%	100	
SUSPENDED SOLIDS	mg/L	19	
VOLATILE SUSPENDED SOLIDS	mg/L	19	
CHEMICAL OXYGEN DEMAND	mg/L	760	
TOTAL CARBON	mg/L	230	
TOTAL ORGANIC CARBON	mg/L	230	
BOD5	mg/L	153	
pH		4.74	
ACIDITY, pH3.7	mg CaCO3/L	0	
, pH8.3	mg CaCO3/L	30	
TOTAL VOLATILE ACIDS	mg AcH/L	30	
COLOUR, TRUE	Hazen Units	280	
PHENOLICS	mg Phenol/L	0.636	
AMMONIA	mg N/L	6	
TKN	mg N/L	18	
SULPHATE	mg/L	8.6	
SULPHIDE	mg/L	<1.0	
TOTAL PHOSPHOROUS	mg/L	(a)	
FULVIC ACIDS	mg C/L	<5	
HUMIC ACIDS	mg C/L	<5	
OIL & GREASE	mg/L	(a)	
MICROTOX, 5 min EC50	%	23	
MICROTOX, 15 min EC50	%	23	

(a) Insufficient sample

TABLE 4.3-2
UNIVERSITY de SHERBROOKE-LOW INTENSITY PROCESS
ACID EXTRACTABLE POLLUTANTS

		FILTRATE
PHENOL	mg/L	< .03
2-NITROPHENOL	mg/L	< .03
2,4-DIMETHYLPHENOL	mg/L	< .03
p-CHLOROPHENOL	mg/L	< .03
4-CHLORO-m-CRESOL	mg/L	< .03
2,4,6-TRICHLOROPHENOL	mg/L	< .03
2,4-DINITROPHENOL	mg/L	< .06
4-NITROPHENOL	mg/L	< .03
2,3,4,5-TETRACHLOROPHENOL	mg/L	< .03
4,6-DINITRO-o-CRESOL	mg/L	< .06
PENTACHLOROPHENOL	mg/L	< .06

TABLE 4.3-3
UNIVERSITE de SHERBROOKE-LOW INTENSITY PROCESS
METAL RESULTS

		FILTRATE
SODIUM	mg/L	<1
POTASSIUM	mg/L	1.5
CALCIUM	mg/L	18
MAGNESIUM	mg/L	1.6
ALUMINIUM	mg/L	<.5
BORON	mg/L	<1
BERYLLIUM	mg/L	<0.003
PHOSPHORUS	mg/L	<.03
COBALT	mg/L	<0.03
ZINC	mg/L	.06
MANGANESE	mg/L	.08
IRON	mg/L	1.6
CHROMIUM	mg/L	<.03
NICKEL	mg/L	.04
COPPER	mg/L	<.03
MOLYBDENUM	mg/L	.03
LEAD	mg/L	<.03
BISMUTH	mg/L	1
SILICON	mg/L	.47
CADMIUM	mg/L	<.03
ARSENIC	mg/L	.0054
MERCURY	mg/L	.0003
VANADIUM	mg/L	<.03
ANTIMONY	mg/L	.001

TABLE 4 3-4
UNIVERSITE de SHERBROOKE-LOW INTENSITY PROCESS
HPLC RESULTS

		FILTRATE
GLUCURONIC ACID	mg/L	<10
GALACTURONIC ACID	mg/L	153
ARABINOSE	mg/L	<10
XYLOSE	mg/L	<10
RHAMNOSE	mg/L	<10
GLUCOSE	mg/L	<10
FURFURAL	mg/L	< 5
HYDROXY METHYL FURFURAL	mg/L	< 5

TABLE 4 3-5
UNIVERSITE de SHERBROOKE-LOW INTENSITY PROCESS
ION CHROMATOGRAPHY

			FILTRATE
SUCCINATE		mg/L	<5
GLYCOLATE		mg/L	<5
OXALATE		mg/L	3
MALONATE		mg/L	<5
MALEATE		mg/L	<5
TARTRATE		mg/L	<5
FORMATE		mg/L	<1
ACETATE		mg/L	<1
PROPIONATE		mg/L	<1
CHLORIDE	(a)	mg/L	5
BROMIDE		mg/L	<1
NITRITE		mg N/L	<1
NITRATE		mg N/L	<1
ORTHO-PHOSPHATE		mg P/L	<1

(a) Determined by wet chemical technique

4.4 McGill University - Peat Dewatering with Microbial Products

Pressates from ten small scale experiments of peat dewatering with microbial products were combined into a single sample from which all analyses were performed. The sample size (100 mL) was too small to permit the analysis of the pressate for several parameters determined by destructive wet chemical techniques (e.g. total solids, suspended solids and total volatile acids) and for acid extractable priority pollutants and metals analysis (which require a particularly large sample for reasonable detection limits to be realized).

Table 4.4-1 summarizes results reported for several environmental parameters for the filtrate. Tables 4.4-2 and 4.4-3 show the filtrate characteristics determined by high pressure liquid chromatography and ion chromatography respectively.

TABLE 4 4-1
McGILL UNIVERSITY-DEWATERING WITH BIOLOGICAL AGENTS
WET CHEMICAL AND MICROTOX RESULTS

		FEED	FILTRATE
TOTAL SOLIDS	mg/L	84100 (a)	(b)
TOTAL VOLATILE SOLIDS	%		(b)
SUSPENDED SOLIDS	mg/L		(b)
VOLATILE SUSPENDED SOLIDS	mg/L		(b)
CHEMICAL OXYGEN DEMAND	mg/L		1590
TOTAL ORGANIC CARBON	mg/L		480
BOD5	mg/L		<15
pH			4.33
ACIDITY, pH3.7	mg CaCO3/L		(b)
, pH8.3	mg CaCO3/L		(b)
TOTAL VOLATILE ACIDS	mg AcH/L		(b)
COLOUR, TRUE	Hazen Units		5
PHENOLICS	mg Phenol/L		.015
AMMONIA	mg N/L		(b)
TKN	mg N/L		24
SULPHATE	mg/L		15
SULPHIDE	mg/L		(b)
TOTAL PHOSPHOROUS	mg/L		0.7
FULVIC ACIDS	mg C/L		100
HUMIC ACIDS	mg C/L		160
OIL & GREASE	mg/L		(b)
MICROTOX, 5 min EC50	%		>50
MICROTOX, 15 min EC50	%		>50

(a) Analysis by McGill U.
(b) Insufficient sample.

TABLE 4.4-2
McGILL UNIVERSITY-DEWATERING WITH BIOLOGICAL AGENTS
HPLC RESULTS

		FILTRATE
GLUCURONIC ACID	mg/L	<10
GALACTURONIC ACID	mg/L	<10
ARABINOSE	mg/L	<10
XYLOSE	mg/L	<10
RHAMNOSE	mg/L	<10
GLUCOSE	mg/L	134
FURFURAL	mg/L	< 5
HYDROXY METHYL FURFURAL	mg/L	< 5

TABLE 4.4-3
MCGILL U. -DEWATERING WITH MICROBIAL PRODUCTS
ION CHROMATOGRAPHY RESULTS

			FILTRATE
SUCCINATE		mg/L	<5
GLYCOLATE		mg/L	<5
OXALATE		mg/L	<1
MALONATE		mg/L	<5
MALEATE		mg/L	<5
TARTRATE		mg/L	<5
FORMATE		mg/L	<1
ACETATE		mg/L	<1
PROPIONATE		mg/L	<1
CHLORIDE	(a)	mg/L	6
BROMIDE		mg/L	<1
NITRITE		mg N/L	<1
NITRATE		mg N/L	0.3
ORTHO-PHOSPHATE		mg P/L	<1

(a) Determined by wet chemical technique.

4.5 CRIQ - Rotary Press

Samples, raw and feed peats and pressate, were obtained from the pilot scale rotary press developed by the Centre de Researche Industrie de Québec. Table 4.5-1 summarizes the results of wet chemical and microbial toxicity analyses of the feed slurries and pressates. Selected metals and acid extractable priority pollutants determined in the two samples are shown in Tables 4.5-2 and 4.5-3. It is likely that the use of municipal water to dilute the raw peat was the origin of increased metals content (notably sodium and silicon) in the peat feed slurry.

Tables 4.5-4 and 4.5-5 summarize the characteristics of pressate from the rotary press as determined by high pressure liquid chromatography and ion chromatography respectively.

TABLE 4 5-1

CRIO-PRESS WET CHEMICAL AND MICROTOX RESULTS

		RAW FEAT	FEED	PRESSATE
TOTAL SOLIDS	mg/L	99250	49840	14400
TOTAL VOLATILE SOLIDS	%	93.4	93.4	94.9
SUSPENDED SOLIDS	mg/L			14300
VOLATILE SUSPENDED SOLIDS	mg/L			13800
CHEMICAL OXYGEN DEMAND	mg/L	180000	73600	25400
TOTAL CARBON	mg/L	57000		7200
TOTAL ORGANIC CARBON	mg/L	52000		7200
BOD5	mg/L			79
pH			4.01	4.3
ACIDITY, pH3.7	mg CaCO3/L			
, pH8.3	mg CaCO3/L		1570	454
TOTAL VOLATILE ACIDS	mg AcH/L			20
COLOUR, TRUE	Hazen Units			320
PHENOLICS	mg Phenol/L	.076	.018	.01
AMMONIA	mg N/L		5	<1
TKN	mg N/L	1370	552	207
SULPHATE	mg/L			29
SULPHIDE	mg/L			<1
TOTAL SULPHUR	mg/L	80		
TOTAL PHOSPHORUS	mg/L			4.6
FULVIC ACIDS	mg C/L	3900	1380	300
HUMIC ACIDS	mg C/L	9600	5600	1700
OIL & GREASE	mg/L		100	42
MICROTOX, 5 min EC50	%			>50
MICROTOX, 15 min EC50	%			>50

TABLE 4.5-2
CRIQ-PRESS METAL RESULTS

		RAW PEAT	FEED	PRESSATE
SODIUM	mg/L	<5	10	8.8
POTASSIUM	mg/L	13	7.3	2
CALCIUM	mg/L	300	111	11
MAGNESIUM	mg/L	49	18	3.2
ALUMINIUM	mg/L	51	21	.08
BORON	mg/L	<0.2	<0.5	.07
BERYLLIUM	mg/L	<0.2	.003	<0.001
PHOSPHORUS	mg/L	10	4.6	.07
COBALT	mg/L	<0.2	<0.03	.01
ZINC	mg/L	8	1.9	.12
MANGANESE	mg/L	2	.96	.1
IRON	mg/L	82	52	.1
CHROMIUM	mg/L	<0.2	.03	.01
NICKEL	mg/L	<0.2	.59	.02
COPPER	mg/L	.34	.08	<0.01
MOLYBDENUM	mg/L	.76	.35	.02
LEAD	mg/L	<0.2	<0.03	.03
BISMUTH	mg/L	<0.2	<1	.02
SILICON	mg/L	<5	6.7	5.9
CADMIUM	mg/L	<0.2	<0.03	<0.01
ARSENIC	mg/L	.021	.0096	
MERCURY	mg/L	.0007	.0003	<0.0001
VANADIUM	mg/L	<0.2	.04	.01
ANTIMONY	mg/L	<0.009	.001	

TABLE 4.5-3
CRIQ-PRESS ACID EXTRACTABLE PRIORITY POLLUTANTS

		FEED	PRESSATE
PHENOL	mg/L	<.03	<.03
2-NITROPHENOL	mg/L	<.03	<.03
2,4-DIMETHYLPHENOL	mg/L	<.03	<.03
p-CHLOROPHENOL	mg/L	<.03	<.03
4-CHLORO-m-CRESOL	mg/L	<.03	<.03
2,4,6-TRICHLOROPHENOL	mg/L	<.03	<.03
2,4-DINITROPHENOL	mg/L	<.06	<.06
4-NITROPHENOL	mg/L	<.03	<.03
2,3,4,5-TETRACHLOROPHENOL	mg/L	<.03	<.0
4,6-DINITRO-o-CRESOL	mg/L	<.06	<.06
PENTACHLOROPHENOL	mg/L	<.06	<.06

TABLE 4.5-4
CRIO-PRESS HPLC RESULTS

		PRESSATE
GLUCURONIC ACID	mg/L	<10
GALACTURONIC ACID	mg/L	<10
ARABINOSE	mg/L	<10
RHAMNOSE	mg/L	<10
XYLOSE	mg/L	<10
GLUCOSE	mg/L	207
FURFURAL	mg/L	<0.5
HYDROXY METHYL FURFURAL	mg/L	<.5

TABLE 4.5-5
CRIO-PRESS ION CHROMATOGRAPHY RESULTS

		PRESSATE
SUCCINATE	mg/L	<5
GLYCOLATE	mg/L	4
OXYLALATE	mg/L	<5
MALONATE	mg/L	26
MALEATE	mg/L	<5
TARTRATE	mg/L	<5
FORMATE	mg/L	<1
ACETATE	mg/L	<1
PROPIONATE	mg/L	<1
TOTAL HALIDES (a)	mg/L	
BROMIDE	mg/L	<1
NITRITE	mg N/L	<1
NITRATE	mg N/L	<1
ORTHO-PHOSPHATE	mg P/L	<1
SULPHATE	mg/L	29

(a) Determined by wet chemical technique.

5. DISCUSSION

5.1 Effects of Operating Conditions on the Effluents from Wet Oxidation

Peat feed slurries and effluents from peat processing via wet oxidation were sampled and characterized for three operating conditions employed for two peats of different humification. Temperature was the key variable in the wet oxidation trials which were conducted at 180°C, 200°C and 220°C.

The analytical results characterizing the processing effluents (presented in Section 4.1) show that the potential discharges of most heavy or toxic metals (Table 4.1-10) are not likely to be of significant concern. This is mainly a product of the low concentrations of toxic metals found to be present in the peats employed in this study and their predicted treatability by conventional means, i.e. pH adjustment and precipitation. Some metals were present above drinking water standards, which is expected for the low pH in the filtrate and pressate.

Cadmium and chromium were detected at approximately 10 times the drinking water criteria. Cadmium was mainly filterable and accounted for much of that present in the original peat. Chromium was present in process waters at levels considerably below those in the peat feeds. Lead was mobilized to a significant degree by wet oxidation and also exceeded drinking water criteria. Arsenic was detected at levels slightly above the criteria.

Drinking water standards for iron (0.3 mg/L) and manganese (0.05 mg/L) (related to aesthetic quality) were greatly exceeded by the filtrates and pressates. A significant portion of iron and manganese were removed from the feed peat in the course of wet oxidation.

Similarly, the concentrations of acid extractable priority pollutants determined in the condensates and combined filtrates and pressates were relatively low. Phenol, as would be expected, was the only species detected in significant quantities. The other phenolic compounds detected in measurable quantities were 2-nitrophenol, 2,4-dimethylphenol, 3,6-dinitro-o-cresol, and p-chlorophenol. These compounds were present at concentrations below 1 mg/L. Trials conducted with the two peats generally indicated a positive influence of reaction temperature on the amount and diversity of phenolic compounds determined by gas chromatography.

HPLC analysis of selected samples of vapour and liquid phase wet oxidation effluents revealed minor concentrations of monomeric sugars and related organic acids (Table 4.1-12). These results suggest that substrates fermentable to alcohols are not present in sufficient concentrations for alcoholic fermentations to be attractive.

Formic and acetic acids have been shown to be the predominant volatile organic acid species in the vapour phase condensate sample analyzed by ion chromatography (Table 4.1-11). The same method applied to filtrate and pressate samples reveal that, in addition to acetic and formic acids, glycolic, succinic and oxalic are the major organic acids present. All these compounds are highly amenable to anaerobic digestion. Ion chromatography also revealed minor levels of inorganic salts. The only point of interest is the very low concentrations of phosphate, suggesting that biological treatment would likely require supplemental phosphate to meet nutrient requirements.

An overview of the wet chemical results reveals that the wastewaters contained high levels of some conventional pollutant parameters. The peat wet oxidation effluents are very strong in dissolved organic matter. COD and BOD_5 values are in the range

of several thousand mg/L. Ammonia and total kjeldahl nitrogen were also present in high concentrations in most samples. Phenolic compounds varied from fairly high levels in condensate (up to 350 mg/L) to relatively low concentrations in dewatered liquid phase effluents (down to 1.35 mg/L). The liquid phase wastewaters were also highly coloured.

Figures 5.1-1 through 5.1-11 show the concentrations and loadings (kg of waste parameter per tonne of peat dry solids fed to the process) for the parameters noted above. The figures indicate the trends caused by operating the wet oxidation process at decreasing temperature (220°C, 200°C and 180°C) for the highly and medium humified peats.

Figure 5.1-1 shows a general decrease in condensate organic strength with decreasing reactor temperature (Run number 6 was anomalous due to difficulties experienced in maintaining steady conditions during the trial). This trend is expected, given the higher vapour pressures of the volatile organic compounds at increased temperatures, and, hence, their removal to the condensate stream. Volatile organic acids and lower molecular weight alcohols are expected products of wet oxidation.

Figure 5.1-2 indicates that the concentrations of COD, TOC, and BOD_5 in the liquid phase were relatively insensitive to reactor temperatures. Figures 5.1-3 and 5.1-4 summarize the organic loadings at the various operating conditions. They indicate that condensate is sensitive to reactor temperature, but contributes a small portion of the loading compared to the dewatered liquid phase wet oxidation effluents.

Figures 5.1-5 and 5.1-6 show the trends of operating conditions on nitrogen content of condensates and combined filtrates and pressates respectively. Condensate TKN was composed mainly of ammonia. Condensate showed a strong positive relationship between TKN and ammonia concentrations and the reactor temperature. This trend was due to the influence of temperature on vapour pressure. Combined filtrate and pressate did not demonstrate any notable trend. Since these streams were much greater than the condensate, the combined loadings (Figure 5.1-7) also showed no significant change with temperature.

Phenolic compound concentrations in condensate and liquid phase effluents have a strong dependency upon reaction conditions (Figures 5.1-8 and 5.1-9). Phenolics loadings, shown in Figure 5.1-10, confirm the positive effect of wet oxidation temperature, which was observed above from the analyses of specific phenolic compounds. The figures also suggest that the more highly humified peat produced more phenolic substances at the 220^{o}C reactor temperature runs.

Colour values (Figure 5.1-11) generally showed an inverse trend with reactor temperature (Run number 6 was likely anomalous, as noted above).

Humic and fulvic acids also revealed an inverse trend with temperature. These classes of substances are reported by Fuchsman (1980) to be related to the strong colour often associated with peat waters. As might be predicted, the more highly humified peat produced considerably more humic and fulvic acids than the moderately humified peat.

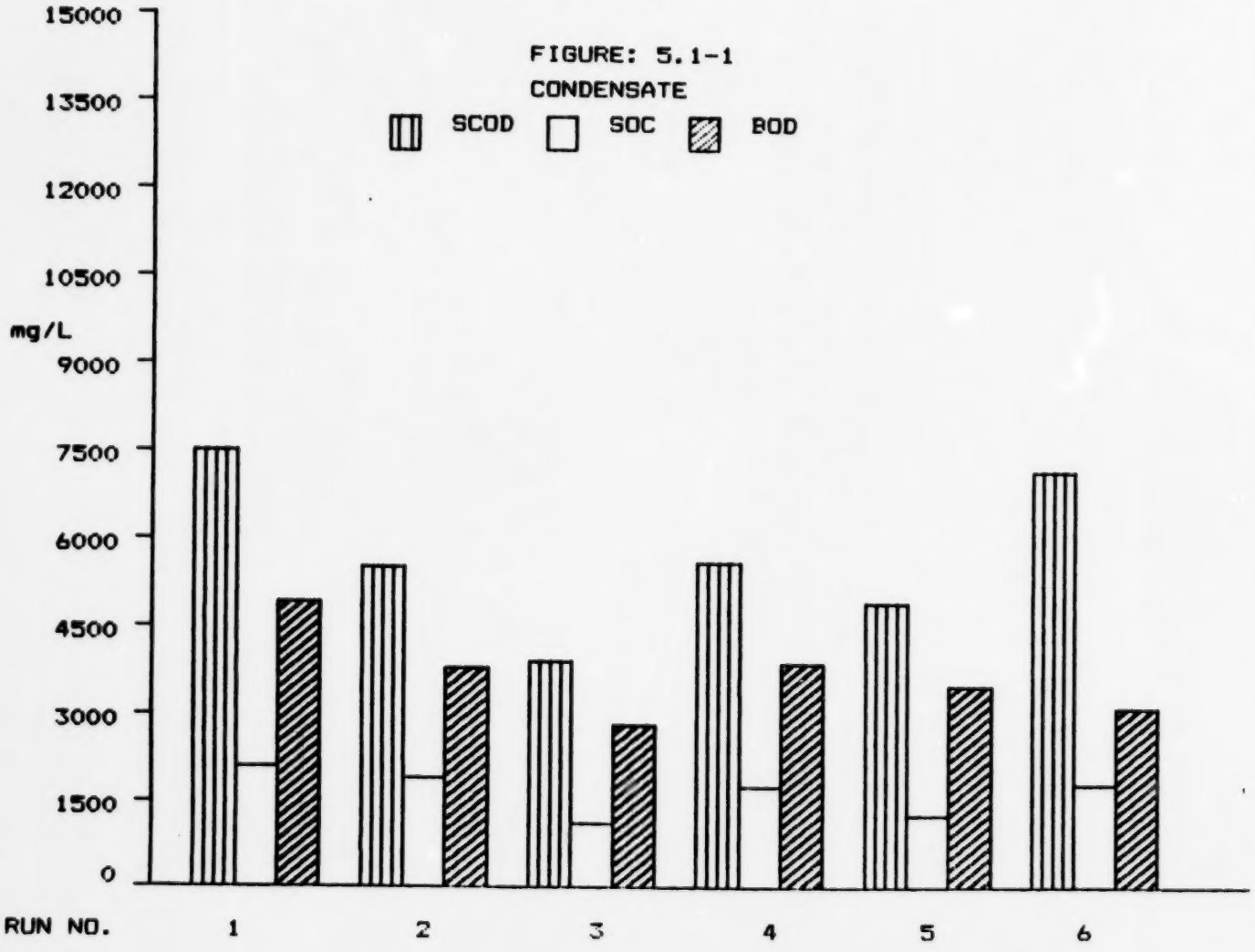
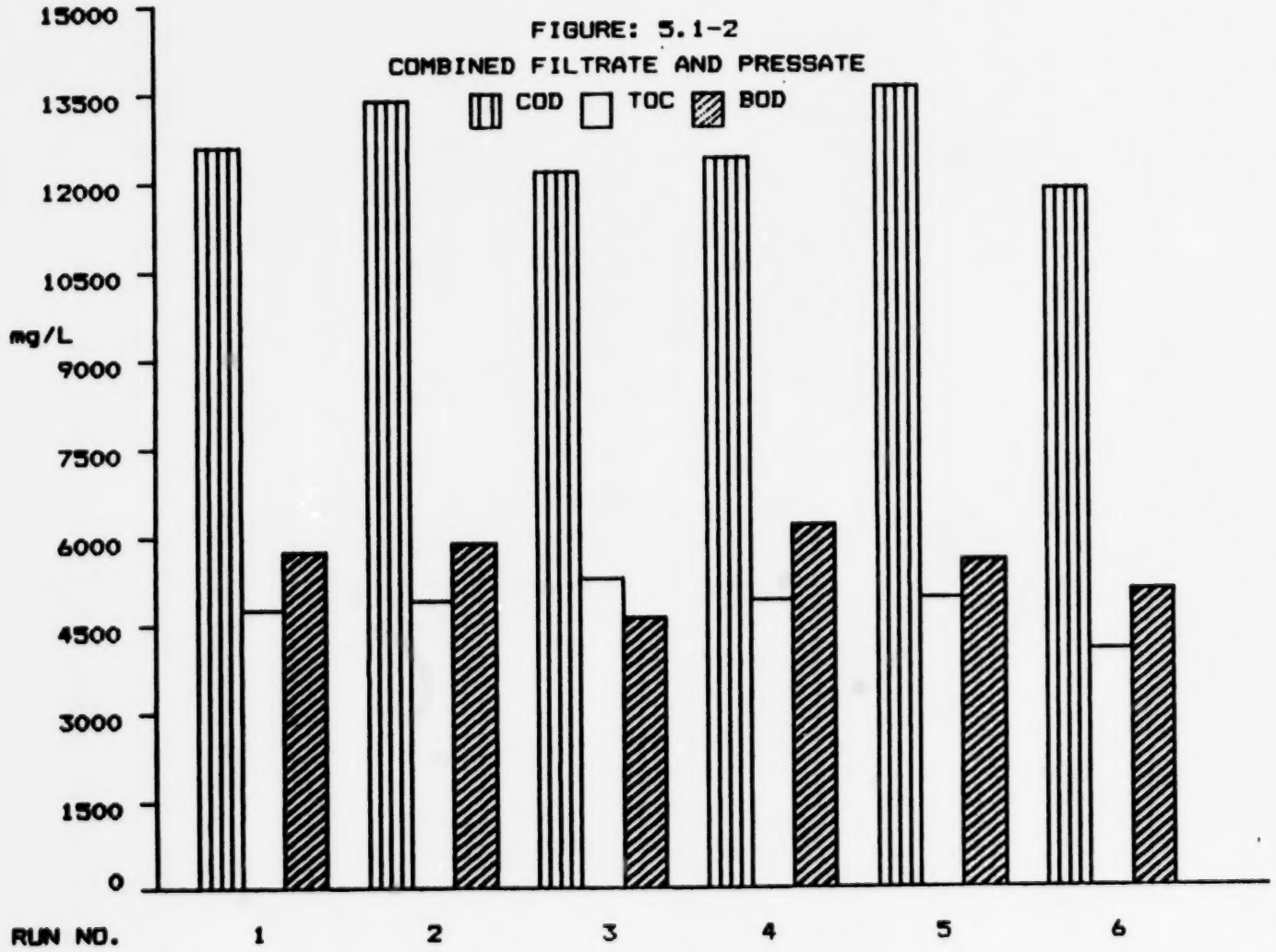


FIGURE: 5.1-1
CONDENSATE
SCOD
SOC
BOD
15000
13500
12000
10500
mg/L
9000
7500
6000
4500
3000
1500
0
RUN NO.
1
2
3
4
5
6

FIGURE: 5.1-2
COMBINED FILTRATE AND PRESSATE



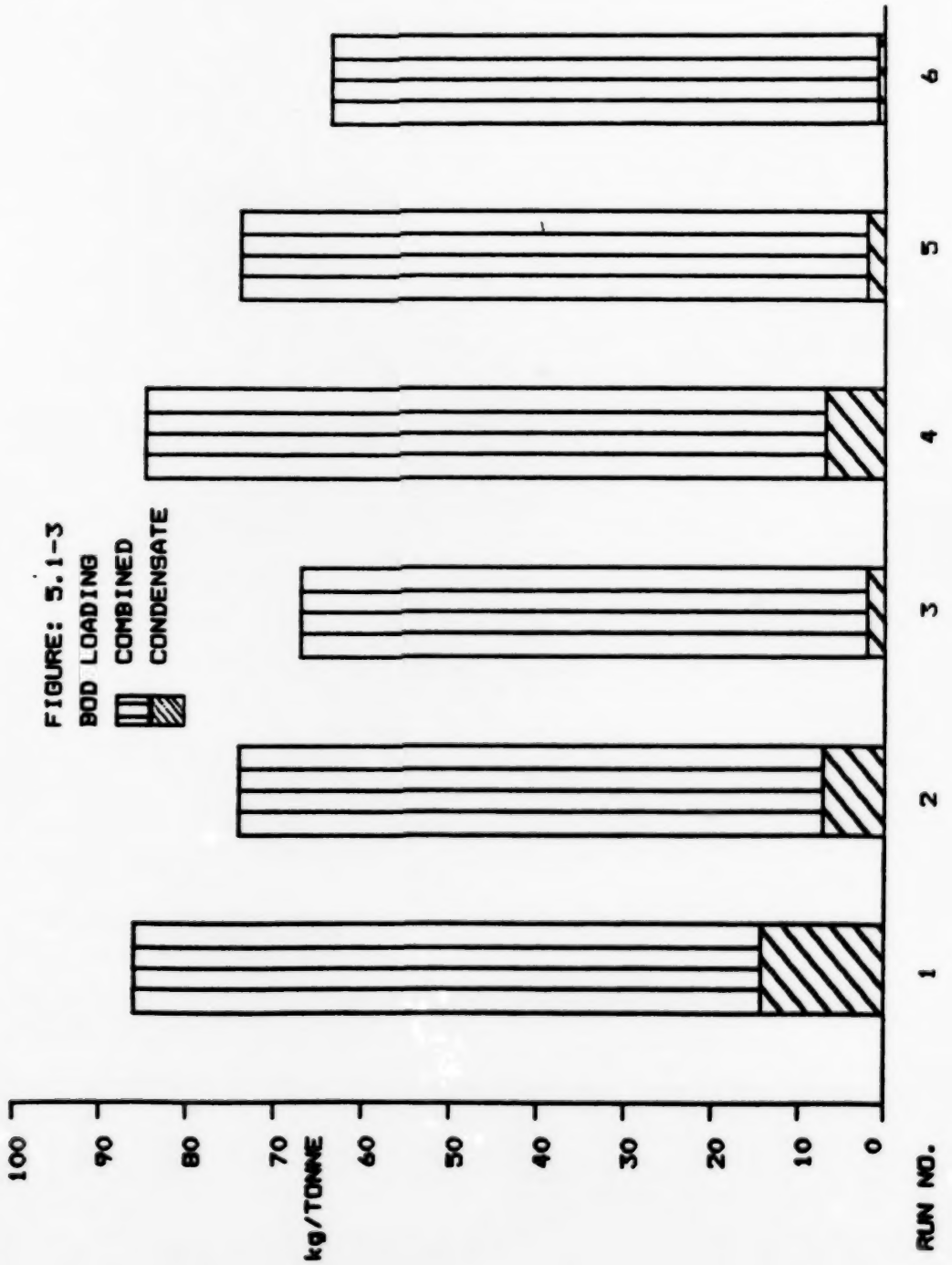


FIGURE: 5.1-3
BOD LOADING
COMBINED
CONDENSATE
kg/TONNE
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
RUN NO.

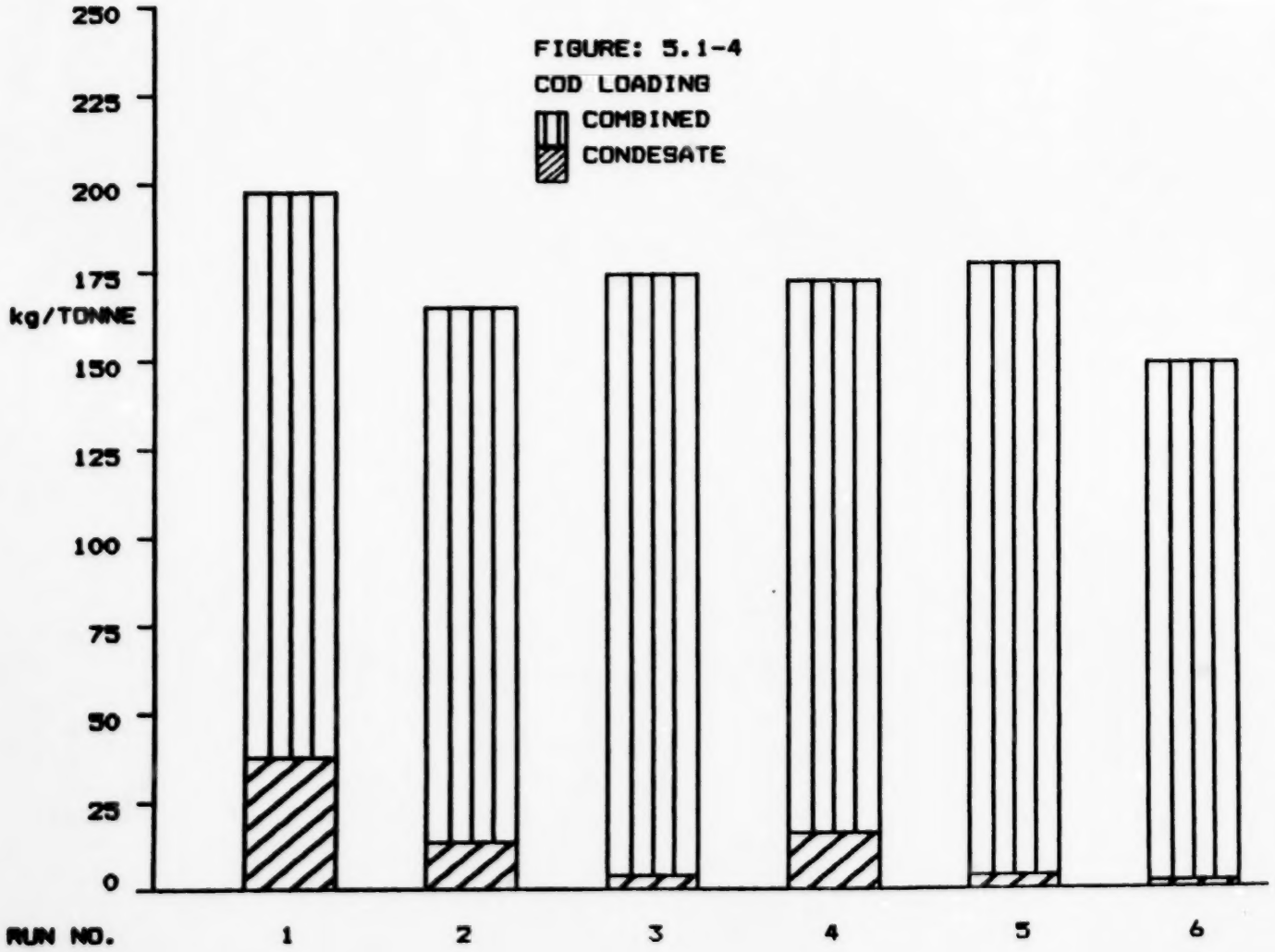

250
225
200
175
kg/TONNE
150
125
100
75
50
25
0
RUN NO.
1
2
3
4
5
6
COD LOADING
COMBINED
CONDESATE

FIGURE: 5.1-4

FIGURE: 5.1-5
CONDENSATE

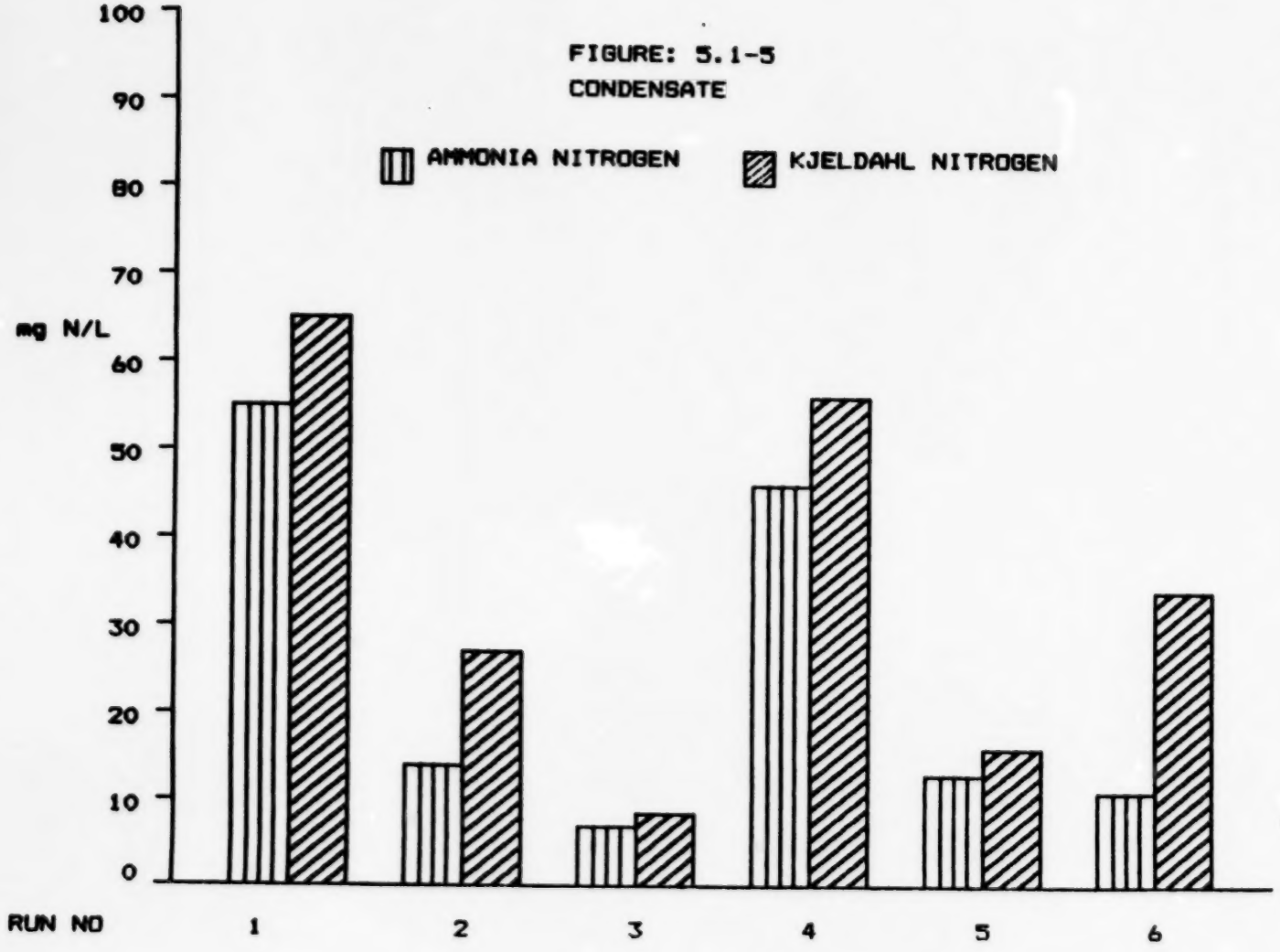


FIGURE: 5.1-6

COMBINED FILTRATE AND PRESSATE

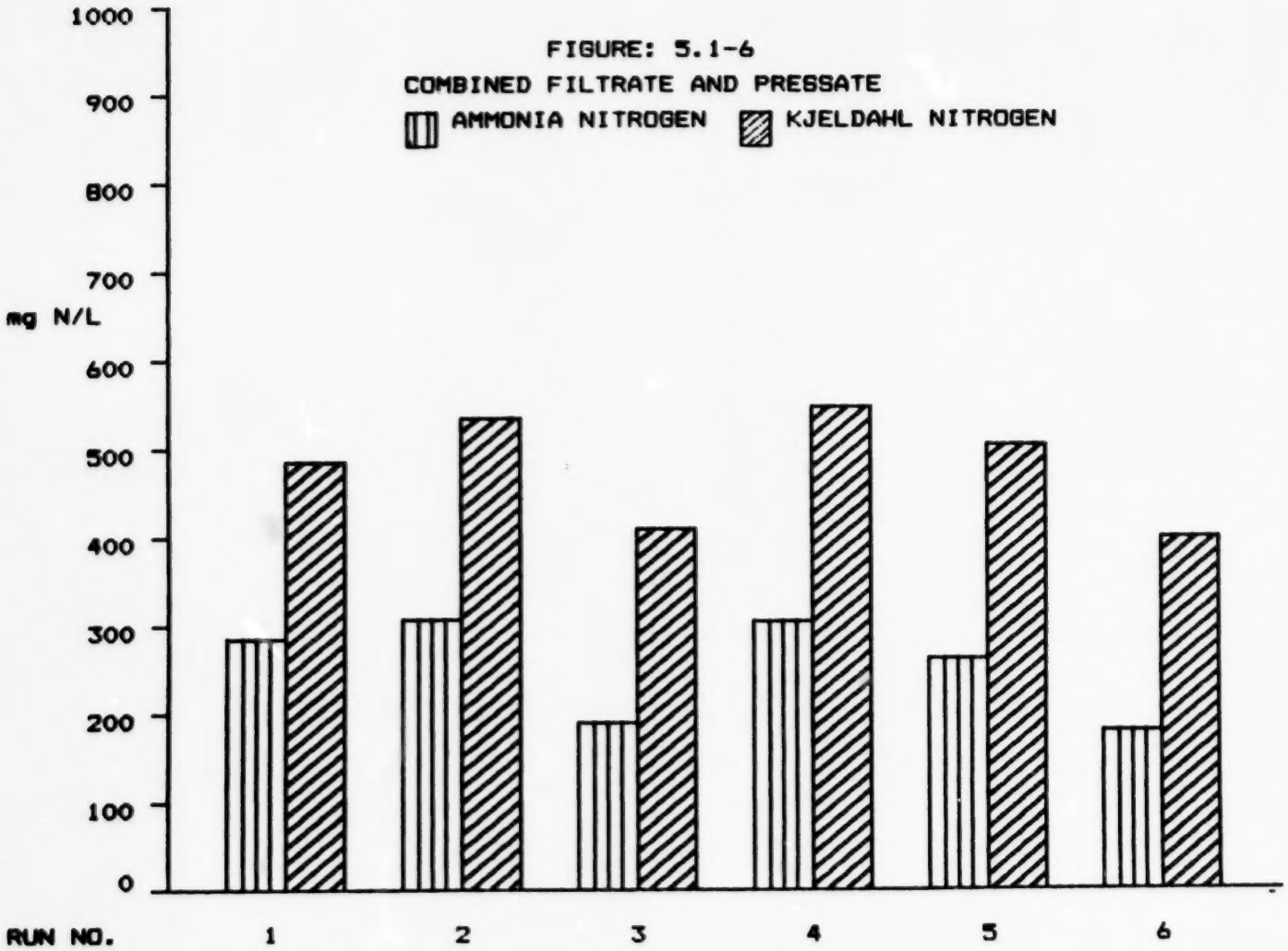


FIGURE: 5.1-7

AMMONIA AND KJELDAHL NITROGEN LOADING

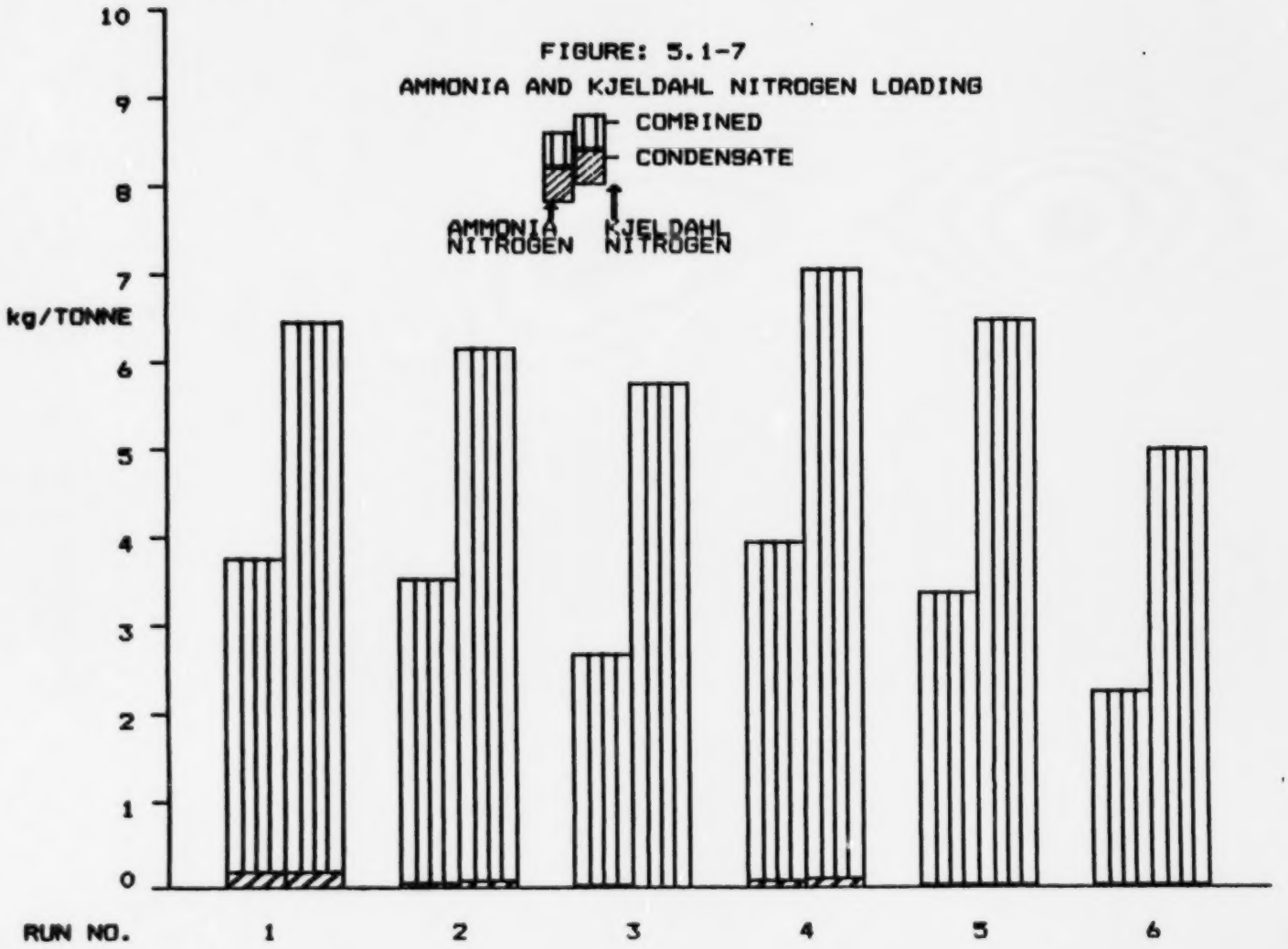


FIGURE: 5.1-8
PHENOLIC COMPOUNDS
CONDENSATE

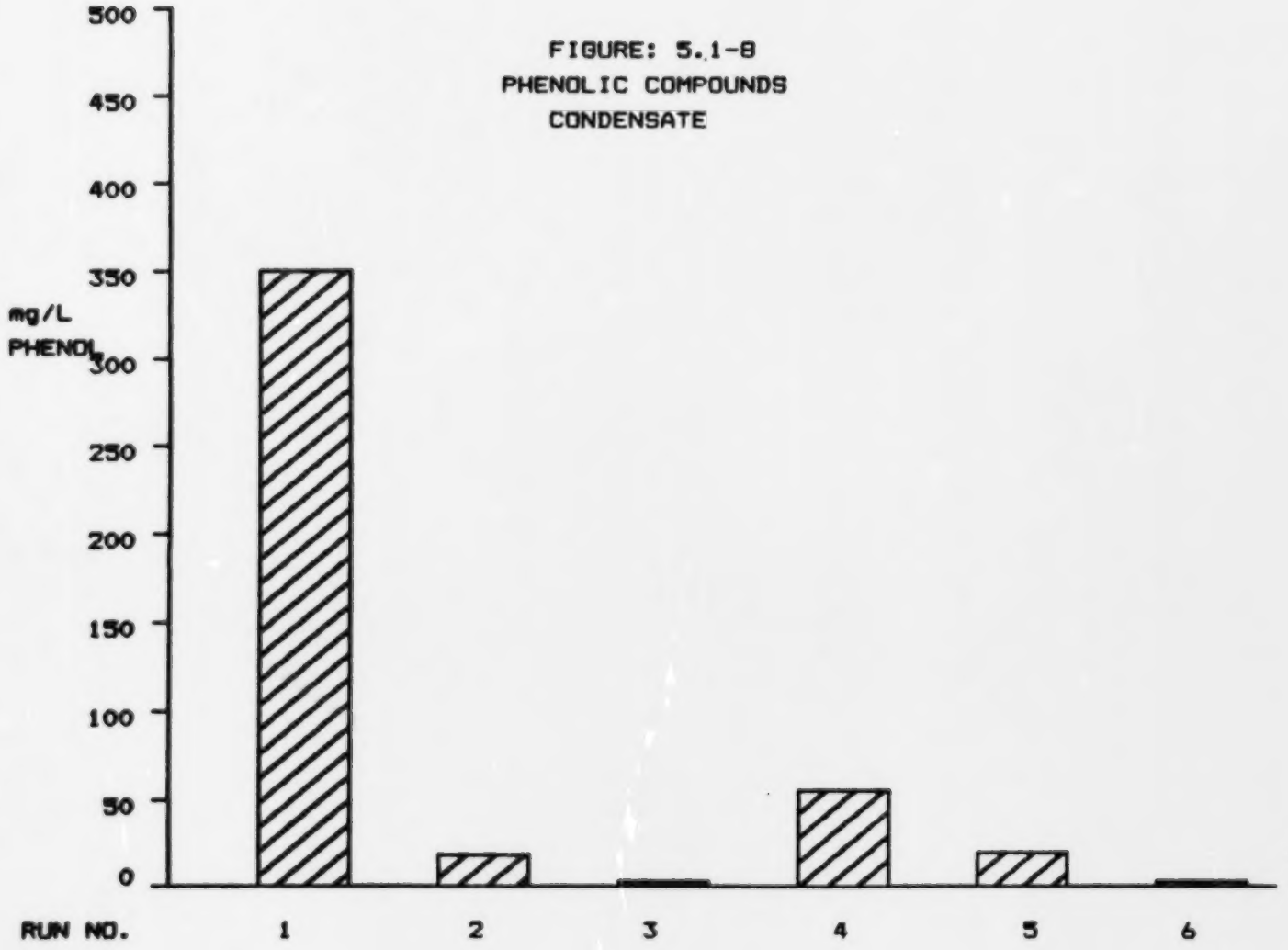
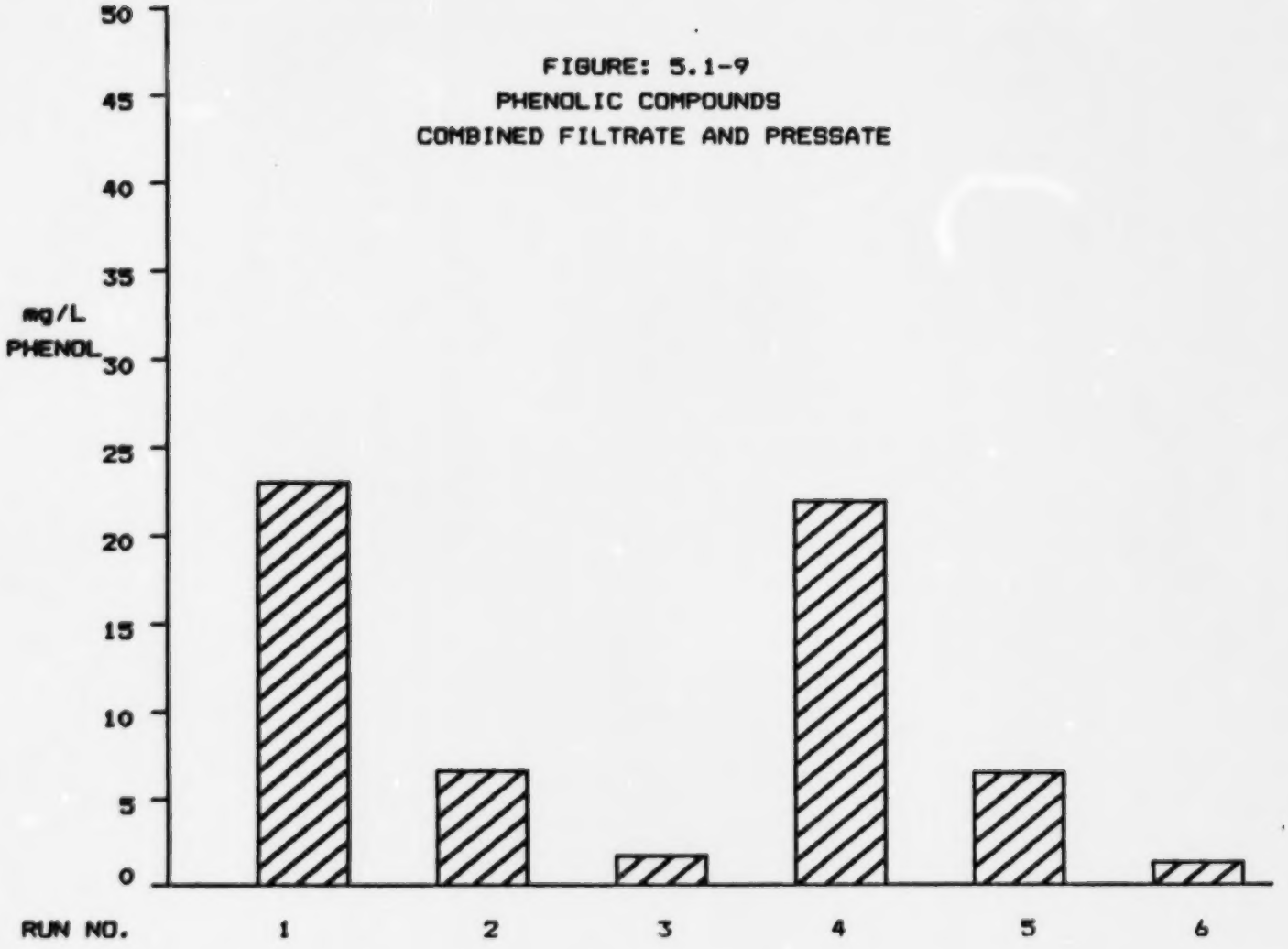


FIGURE: 5.1-9
PHENOLIC COMPOUNDS
COMBINED FILTRATE AND PRESSATE



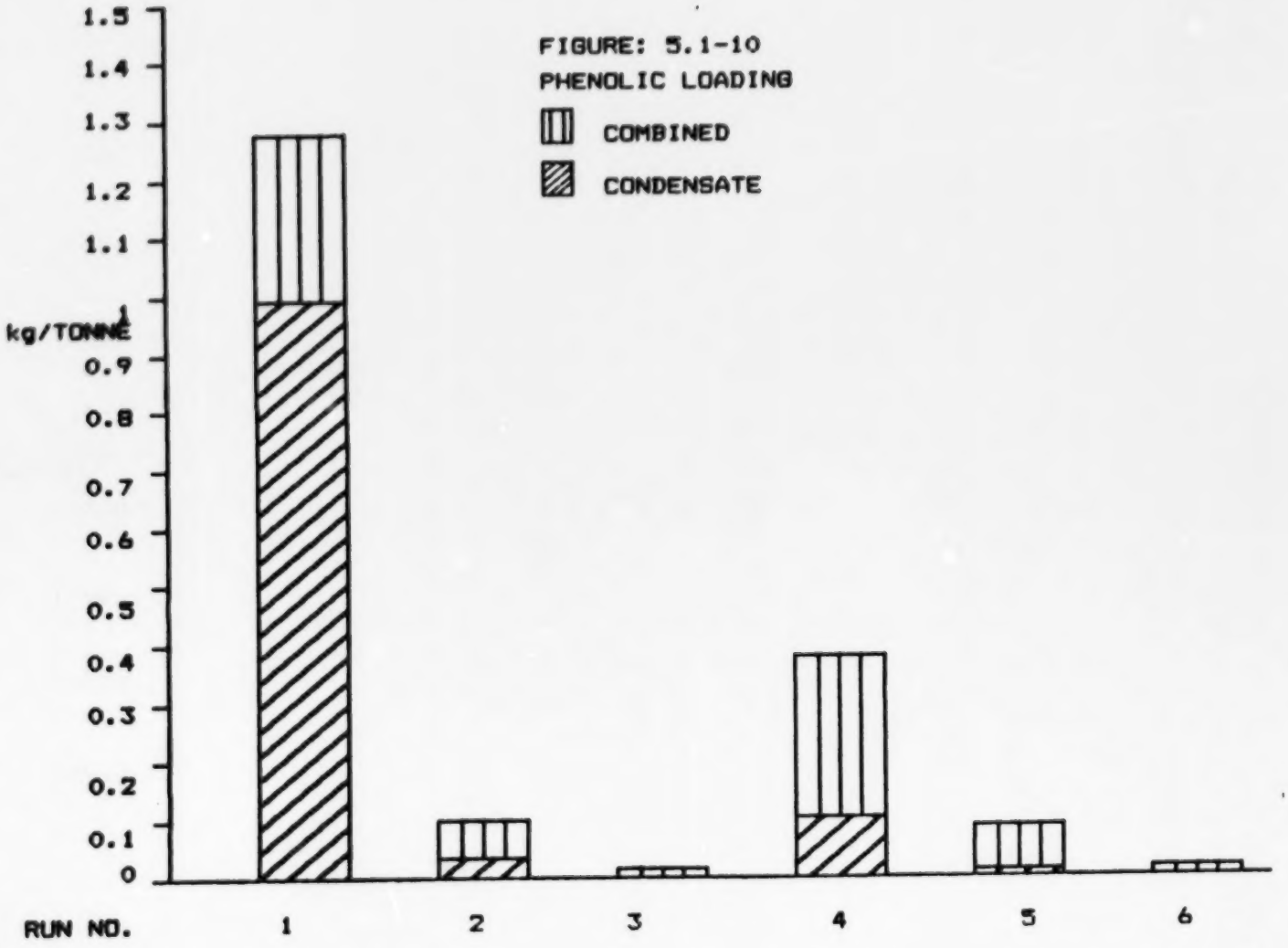
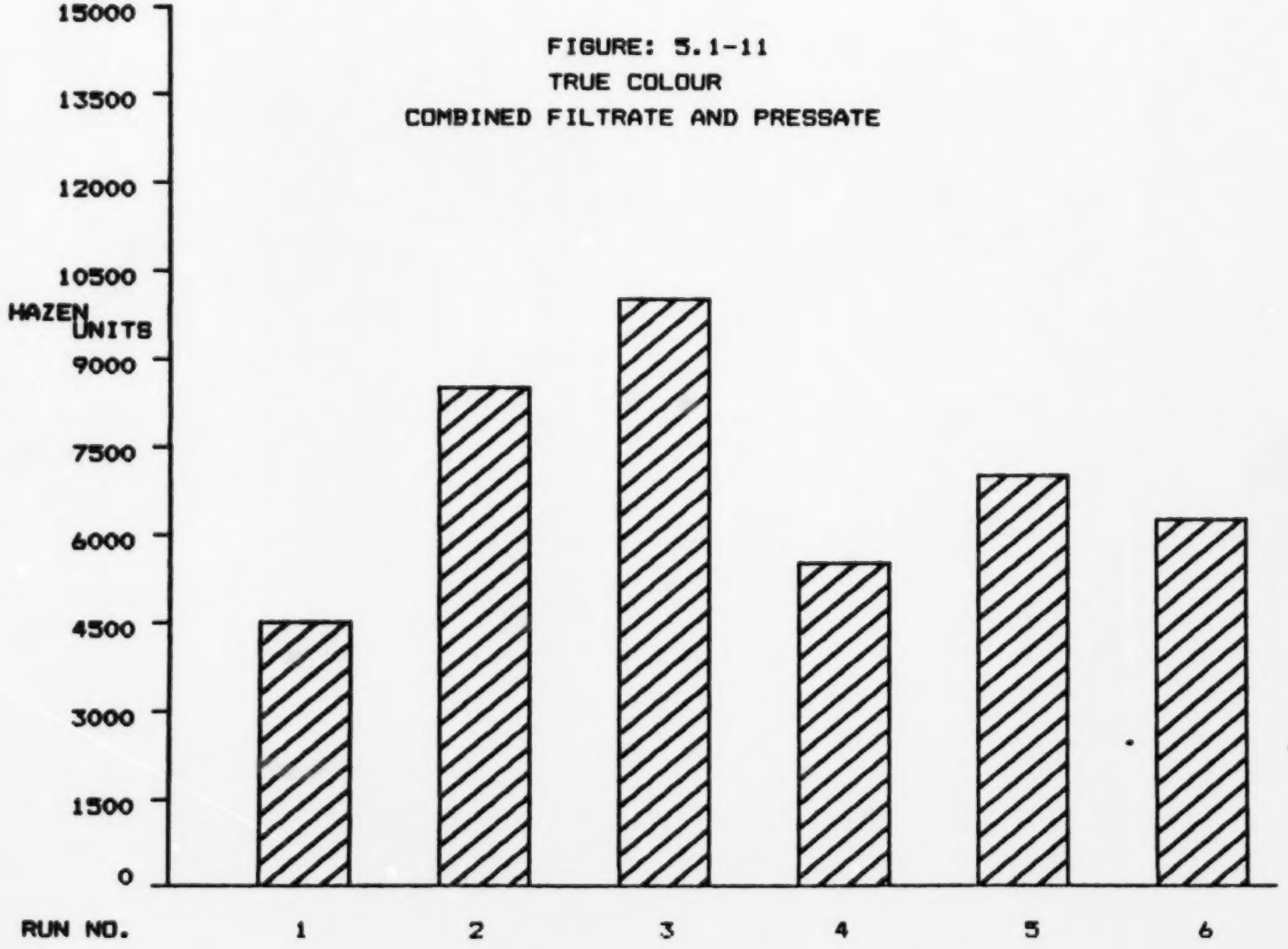


FIGURE: 5.1-10
PHENOLIC LOADING

FIGURE: 5.1-11
TRUE COLOUR
COMBINED FILTRATE AND PRESSATE



5.2 Comparison of Process Waste Characteristics

The five peat dewatering processes whose effluents were studied in this project differed considerably in a number of aspects. The size and degree of development ranged from very small batch apparatus employed by the University groups to the integrated pilot scale units used by the research organizations. Also, four different peat feed materials were used in the processing trials, which, no doubt, influenced the wastewater characteristics. On these, and other bases, the following comparison of waste characteristics and loadings should be viewed with caution.

Acid extractable priority pollutants were not found in high concentrations in any of the processes. The IGT wet carbonization effluents contained phenol (11 mg/L in the condensate and 1.5 mg/L in the filtrate) and measurable amounts of 2-nitrophenol (2 mg/L) and 2,4-dimethylphenol (0.2 mg/L). Wet oxidation trials of peat produced these phenolic compounds at similar concentrations, as well as low levels of 3,6-dinitro-o-cresol, and p-chlorophenol. The other processes showed no quantifiable levels of the target compounds.

Toxic metals were not at environmentally significant concentrations in any of the process effluents. This is due to the low levels of heavy metals present in the feed peats.

IGT wet carbonization filtrate contained levels of lead, chromium and arsenic in excess of drinking water standards established for these toxic metals. Wet oxidized peat liquid effluents exceeded the toxic metal standards for chromium, lead, cadmium and arsenic. Both processes resulted in discharges containing levels of iron and manganese much higher than drinking water standards (based on aesthetic criteria). Aluminum, at 150 mg/L, was at a significant level in the wet oxidized filtrate and pressate.

None of the other peat dewatering processes revealed filtrates with metal concentrations in excess of drinking water standards.

HPLC analysis for monomeric sugars did not reveal high concentrations in any of the process effluents. The CRIQ and McGill University peat dewatering processes revealed low concentrations of glucose (207 mg/L and 134 mg/L respectively). A variety of sugars was detected in the wet oxidized filtrates, viz. arabinose, rhamnose, glucose and xylose. Galacturonic acid was detected at measurable levels in the ORF, IGT and Universite de Sherbrooke samples. (This odoriferous compound apparently gives the characteristic odour of effluents from the thermal processing of peats).

Furfural and hydroxymethyl furfural were present in both the wet oxidation and wet carbonization effluents. The furfural indicated that a significant fraction of the sugars were decomposed in these processes.

Wet oxidation of peat produced significant quantities of acetic and formic acids. IGT wet carbonization produced lower but measurable levels of these volatile organic acids. Other organic acids (succinic, glycolic, oxalic, malonic, and maleic acids) were also detected at high concentrations in the wet oxidized effluent.

Significant concentrations of organic acids were not found in the other peat dewatering processes.

Inorganic anions were not at important levels in any of these processes.

The same conventional parameters, as discussed in the previous section on wet oxidation operating conditions, are of interest for the other peat dewatering processes. Figures 5.2-1 through 5.2-13 compare graphically the effluent concentrations and loadings (in kg per tonne of peat dry solids feed) for key wastewater characteristics. (The values reported for the ORF trials are averages calculated from the six wet oxidation runs).

Figures 5.2-1 and 5.2-2 compare the suspended solids produced. They give an indication of the solids recovery of each process. This, in turn, is more likely a function of the scale of filtration devices employed than other aspects of the peat processes. The CRIQ press, for example, has relatively large openings in its screens, while the Université de Sherbrooke work employed fine filter paper over Buchner funnels.

Organic concentrations and loadings, expressed as BOD_5 and COD, are compared in Figures 5.2-3 through 5.2-6. Biochemical oxygen demand is high from both the wet carbonization and wet oxidation trials. The CRIQ trial shows a high COD. However, this was almost entirely due to peat solids escaping from the process, which would likely be rapidly removed by settlement upon standing. It is notable as well that the CRIQ trial was conducted with a relatively less humified peat, which would yield less soluble matter.

Nitrogen, as ammonia and total kjeldahl nitrogen, are presented in Figures 5.2-7 through 5.2-10. The IGT and ORF results are similar in concentration and loading. Significant discharges are noted for the Université de Sherbrooke and McGill University trials. The CRIQ results are due to organic nitrogen present in the essentially unaltered peat particulate matter.

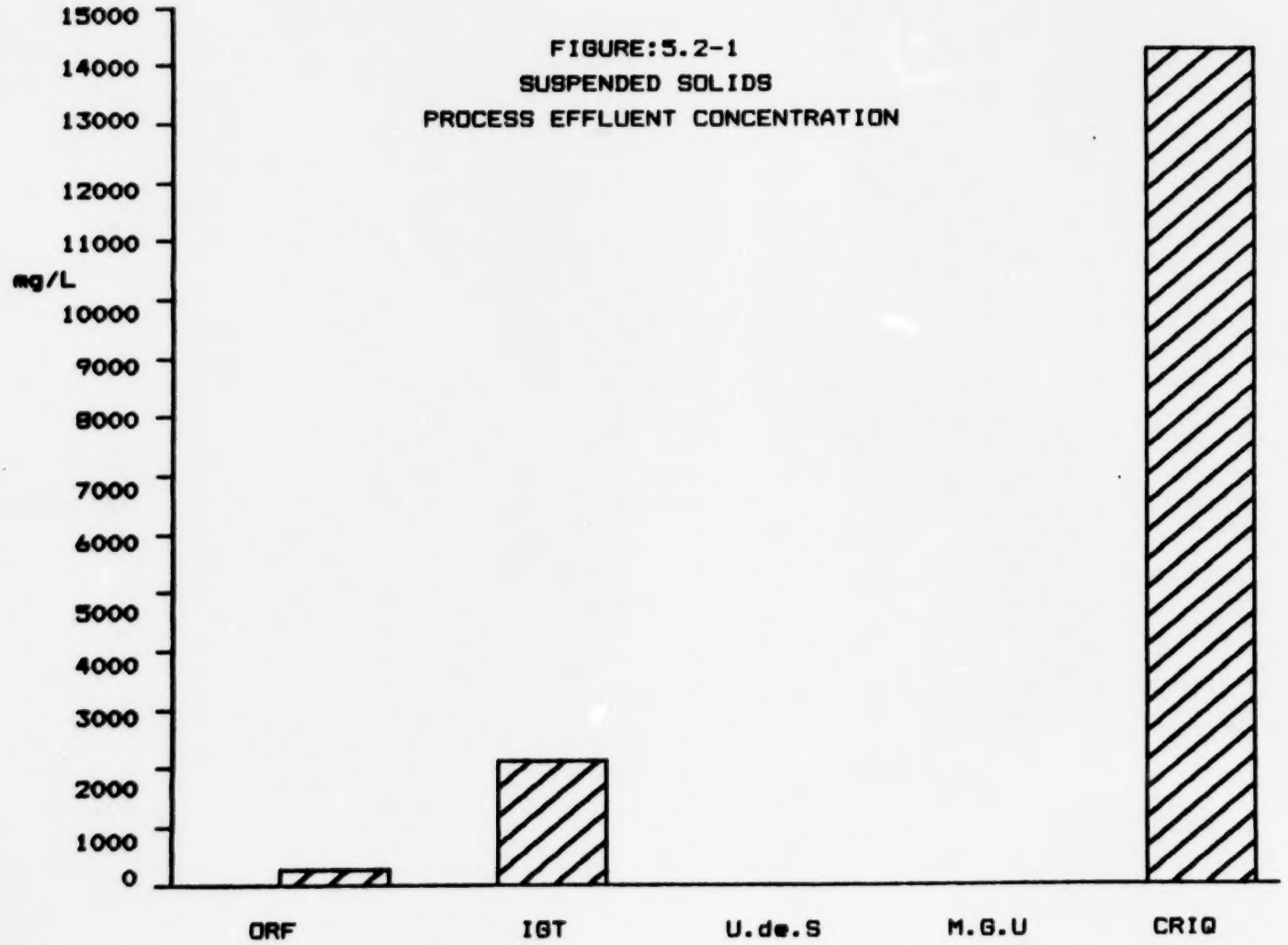
Phenolic compounds from the various processes (illustrated in Figures 5.2-11 and 5.2-12) follow the same pattern. ORF and IGT trials indicated significant potential problems. The other processes demonstrated minor phenolics production.

Wet oxidation trials produced much more highly coloured effluents than the others. The values reported were true colour, with particulate removed. Levels in the Université de Sherbrooke, CRIQ and IGT were much lower, but significant. The McGill University samples had very low colour.

The results of toxicity bioassays are shown in Table 5.2-1. All of the effluents with the exception of the McGill pressate and the CRIQ pressate show a high acute toxicity in the test. Samples of the November 30 combined filtrate and pressate were sent to Environment Canada for a traditional 96-h LC_{50} fish bioassay using Salmo gairdneri. The results show remarkably good agreement with the microbial assay procedures, considering the differences in test organism and assessment methods. The data tend to confirm the usefulness of microbial bioassays and favourable comparison with fish bioassays for the detection of aquatic toxicity reported by McFeters et al (1983).

The CRIQ pressate and McGill pressate showed low acute toxicity as might be expected, since these are non-thermal processes.

FIGURE:5.2-1
SUSPENDED SOLIDS
PROCESS EFFLUENT CONCENTRATION



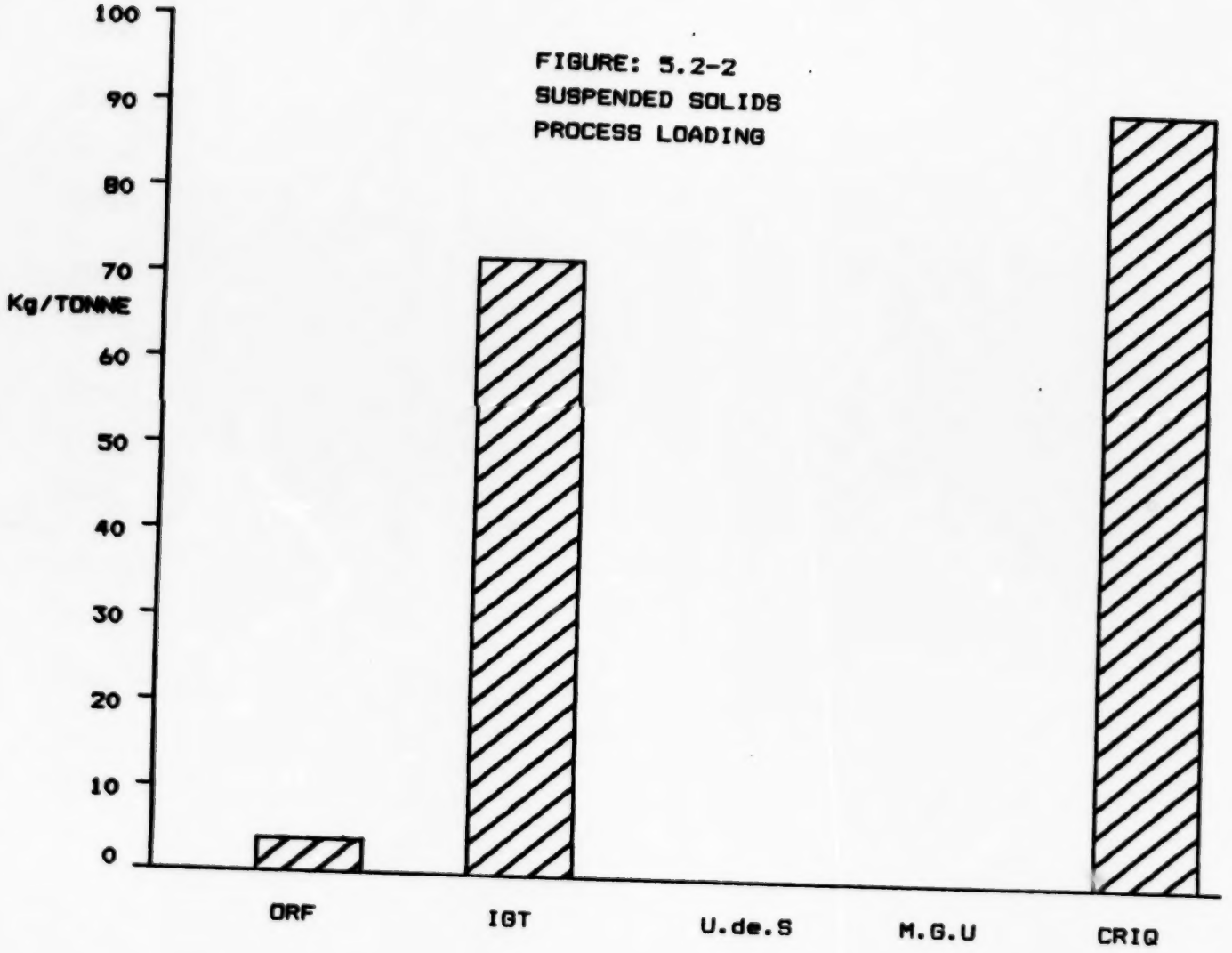


FIGURE: 5.2-2
SUSPENDED SOLIDS
PROCESS LOADING

FIGURE: 5.2-3
BOD
PROCESS EFFLUENT CONCENTRATION

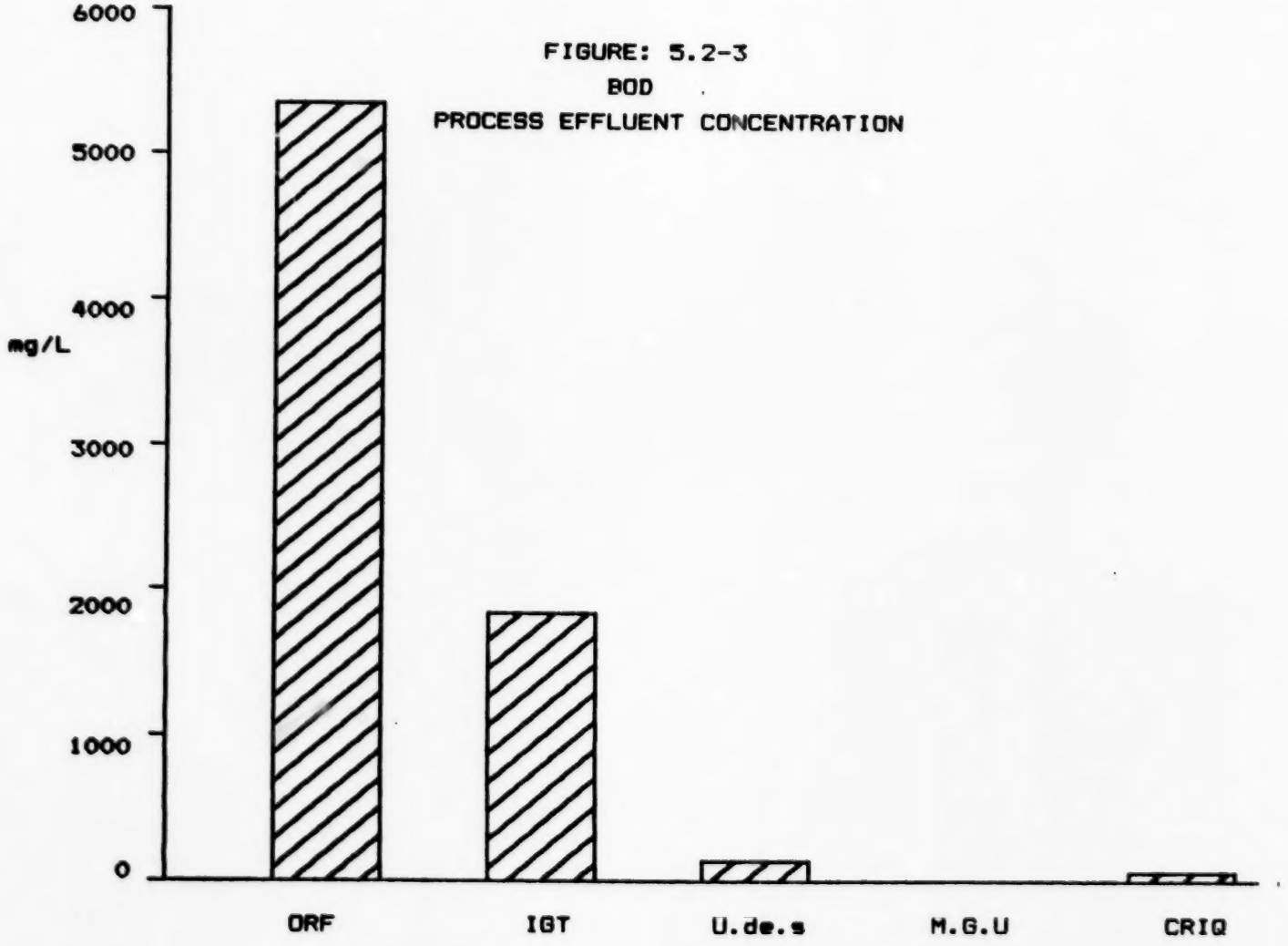


FIGURE: 5.2-4
BOD
PROCESS LOADING

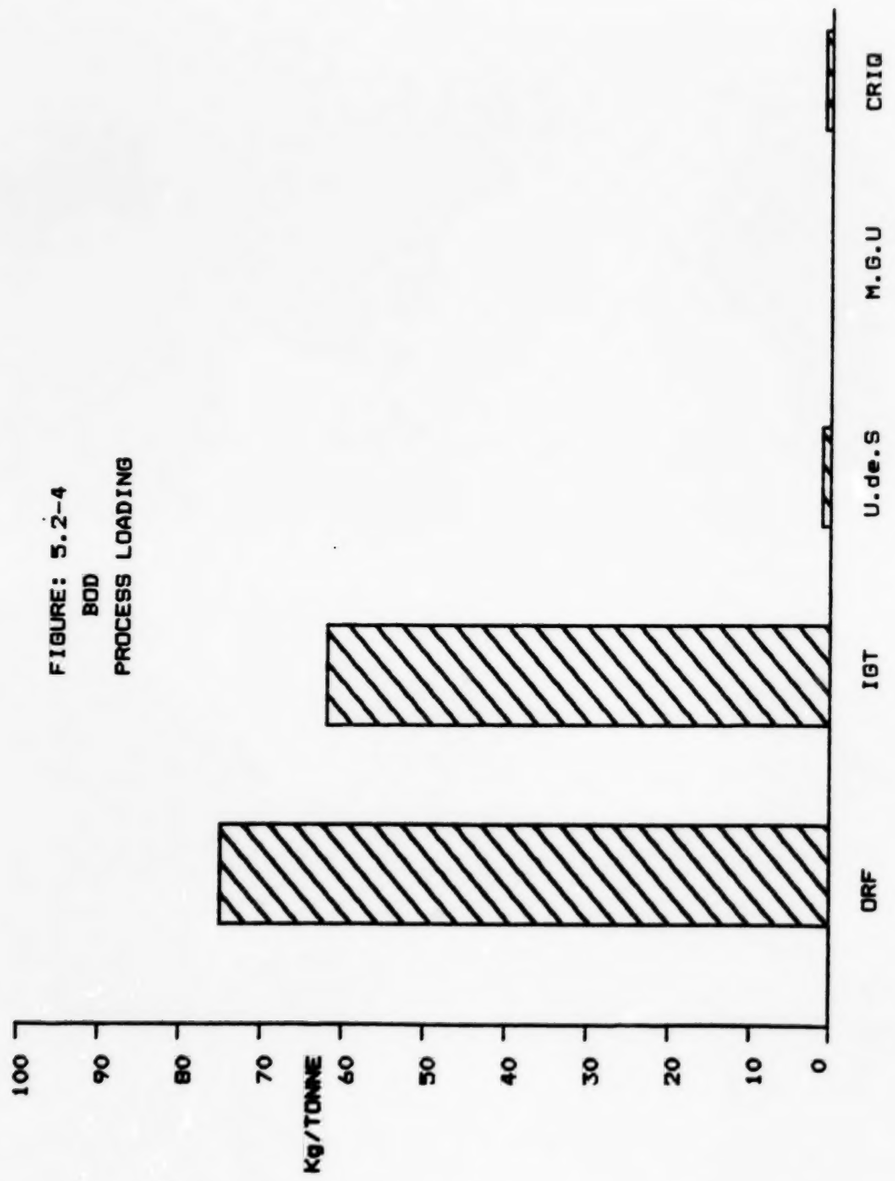
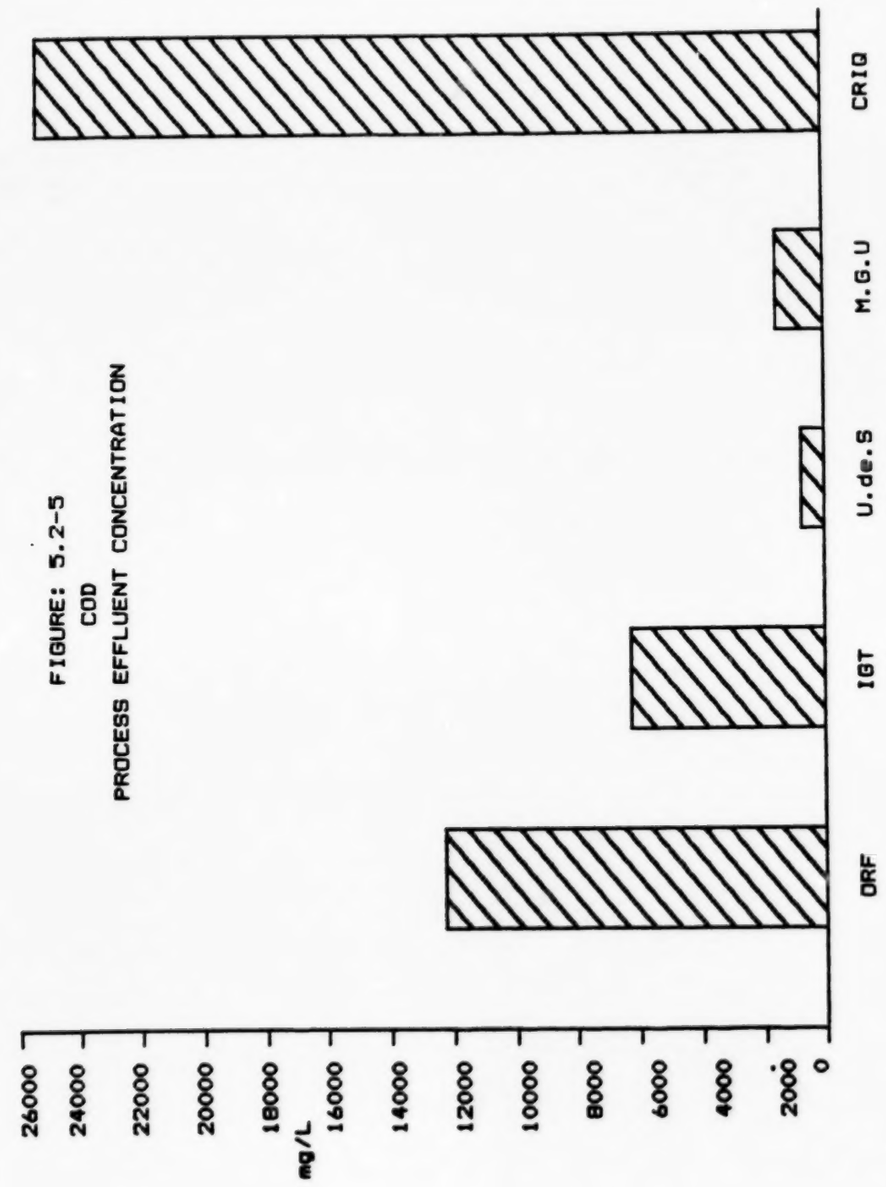


FIGURE: 5.2-5
COD
PROCESS EFFLUENT CONCENTRATION



6.4 McGill University - Peat Dewatering with Microbial Products

Low levels of contaminants were measured in the filtrate from the McGill bench scale trials. The filtrate had no measurable toxicity by the Microtox technique.

Insufficient sample was available from this bench scale process to permit the analysis for priority pollutants or metals. It is most unlikely, however, that the process would release any contaminants of that nature.

Filtrate from the McGill University process was particularly low in colour intensity.

6.5 CRIQ - Rotary Press

The mechanical press developed by the Centre du Recherche Industrielle du Québec was demonstrated with a horticultural peat. The pressate yielded was very high in suspended solids content, highly coloured, and mildly acidic. Concentrations of BOD_5 and ammonia were modest. No measurable toxicity was reported for the pressate.

The CRIQ mechanical dewatering process did not mobilize metals from the feed peat, nor were any acid extractable priority pollutants detectable in the pressate.

FIGURE: 5.2-6
COD
PROCESS LOADING

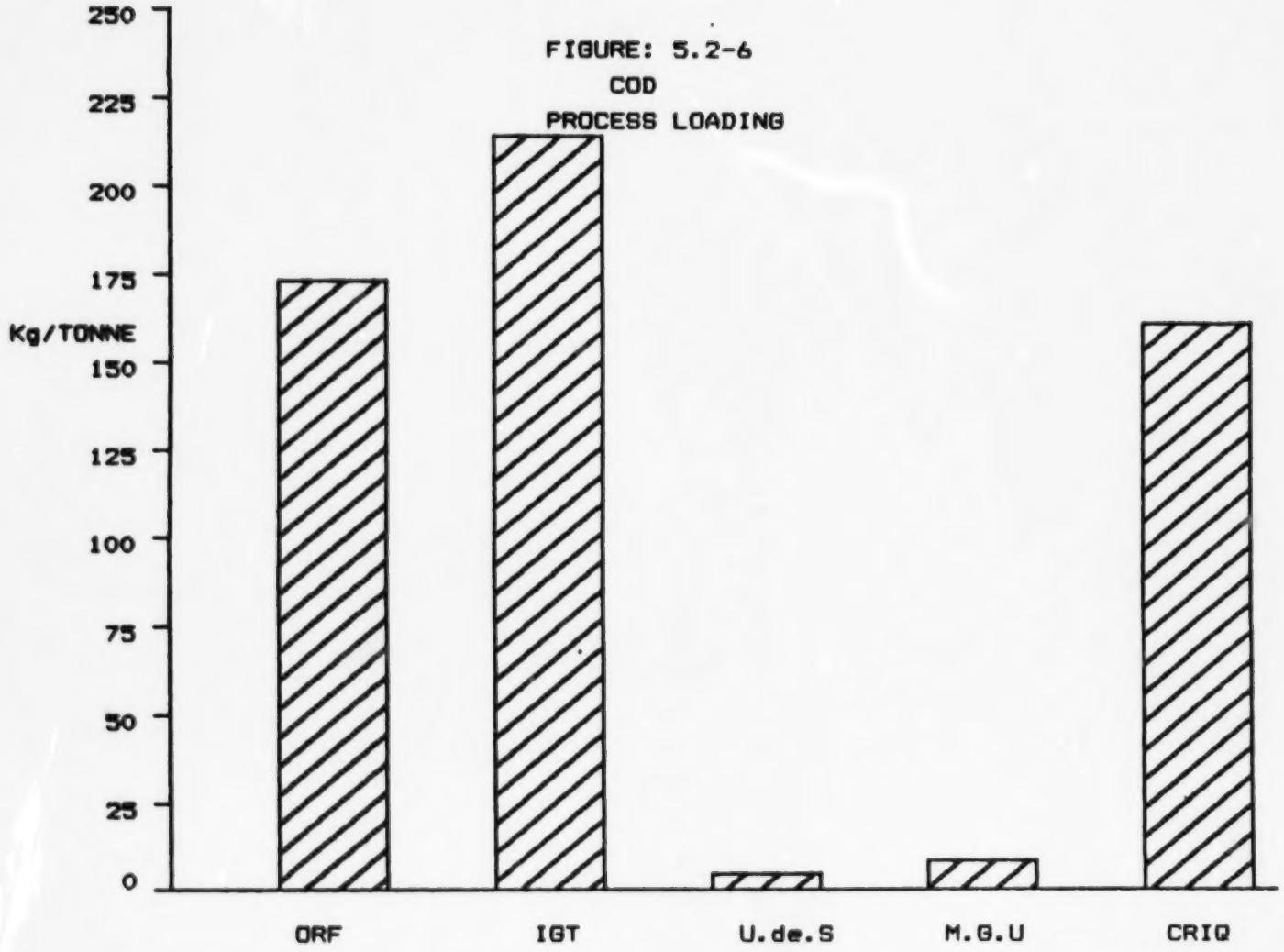


FIGURE: 5.2-7
TKN
PROCESS EFFLUENT CONCENTRATION

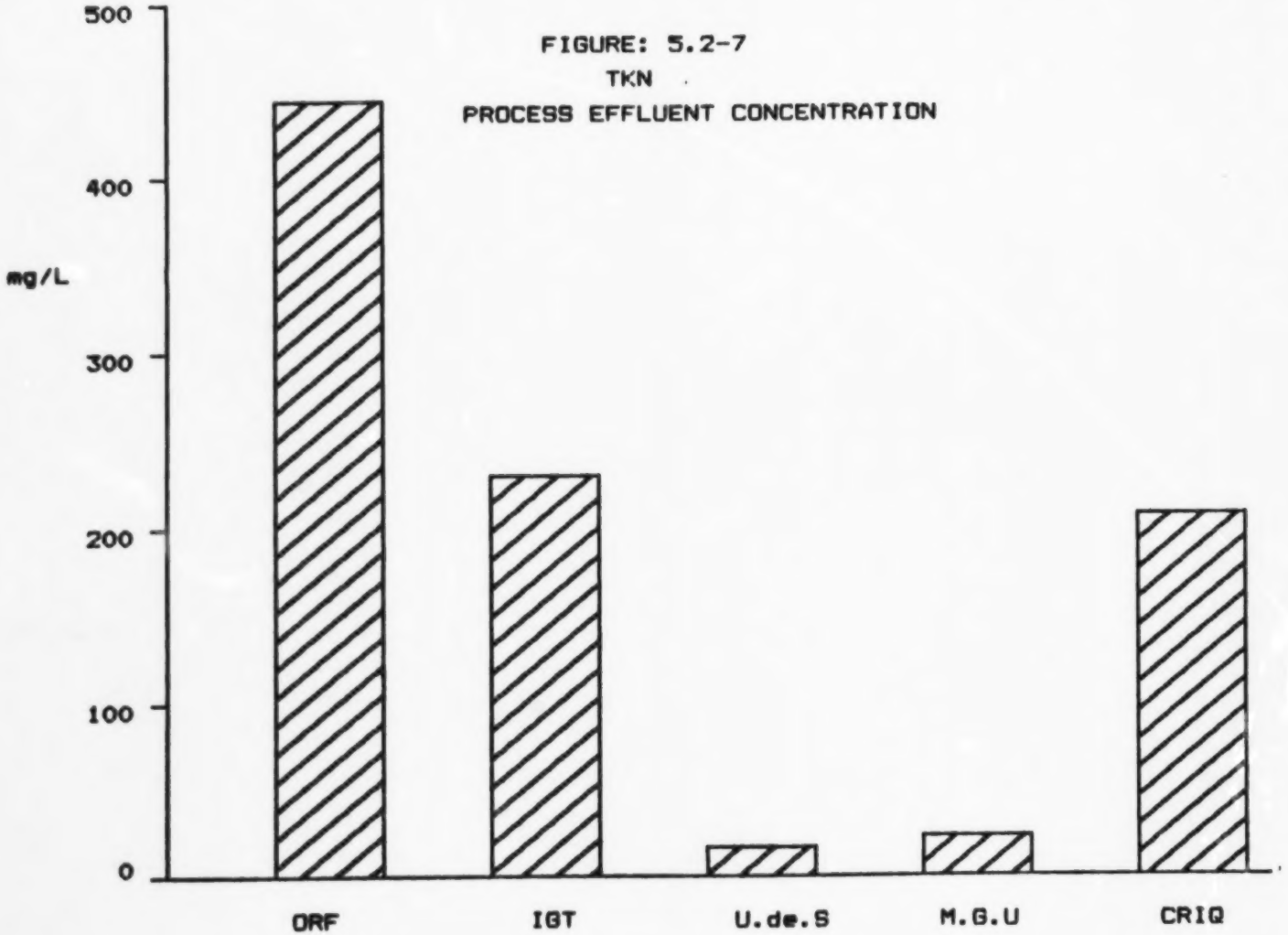


FIGURE: 5.2-8
TKN
PROCESS LOADING

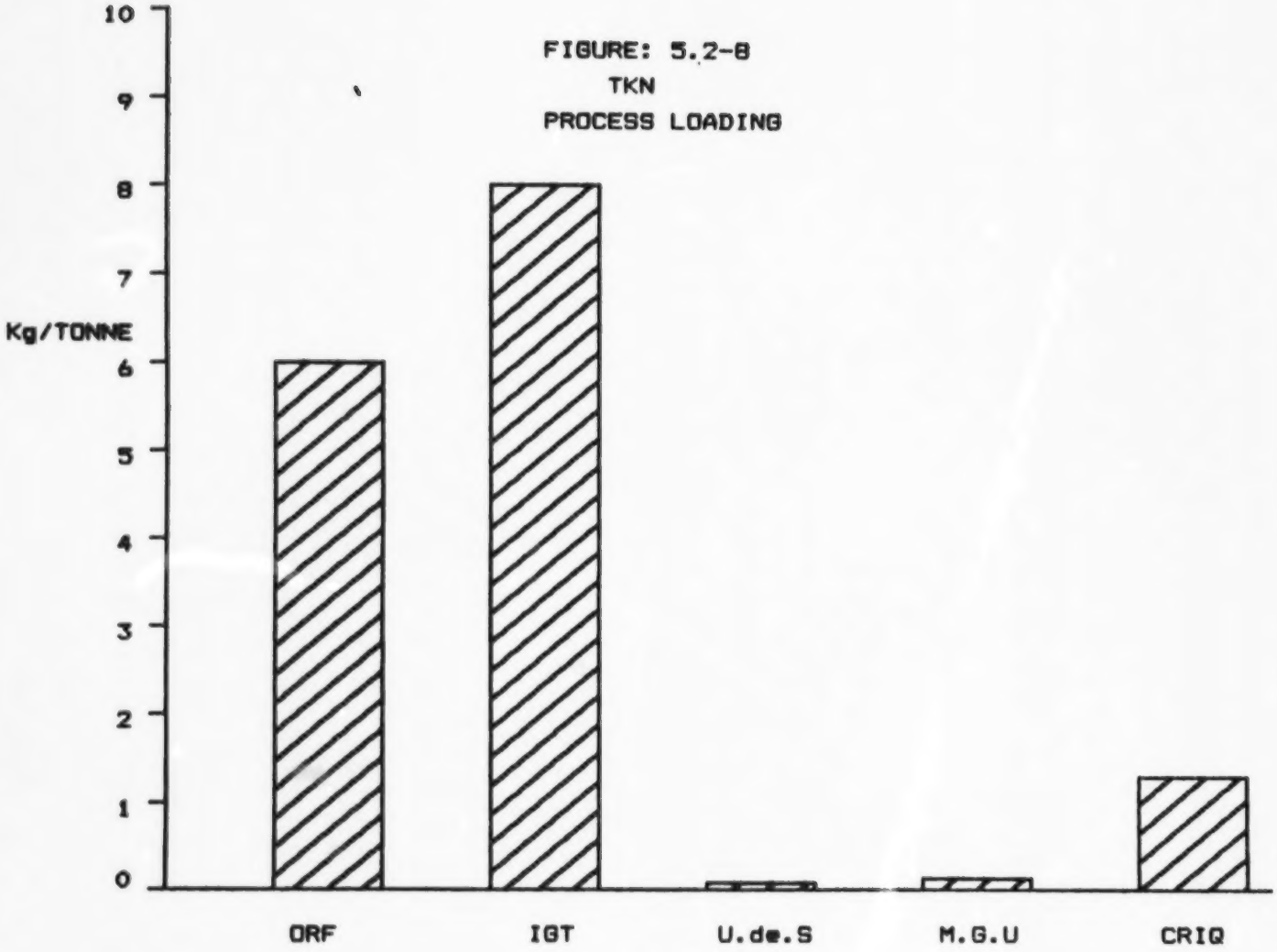


FIGURE: 5.2-9
AMMONIA NITROGEN
PROCESS EFFLUENT CONCENTRATION

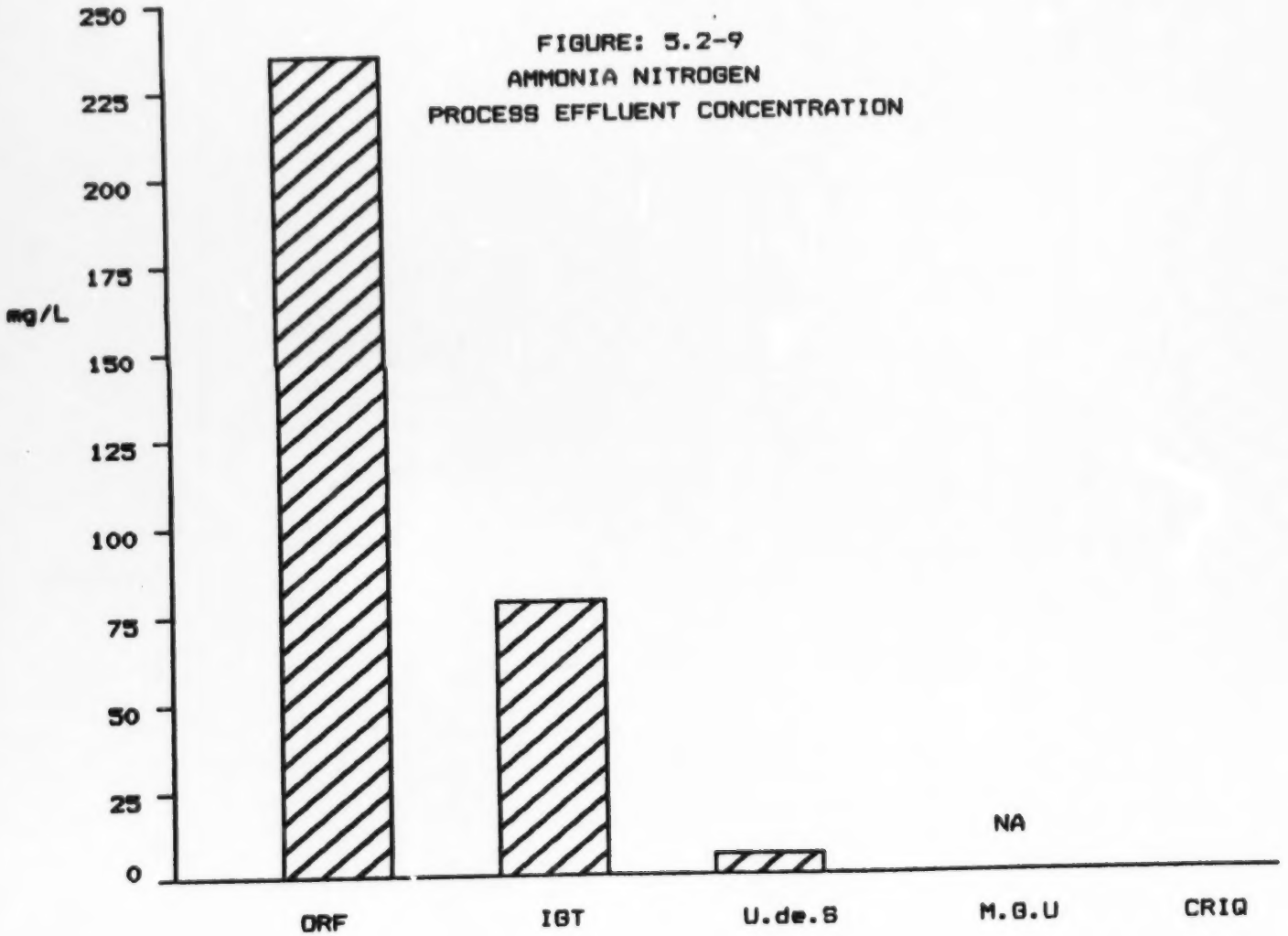


FIGURE: 5.2-10
AMMONIA NITROGEN
PROCESS LOADING

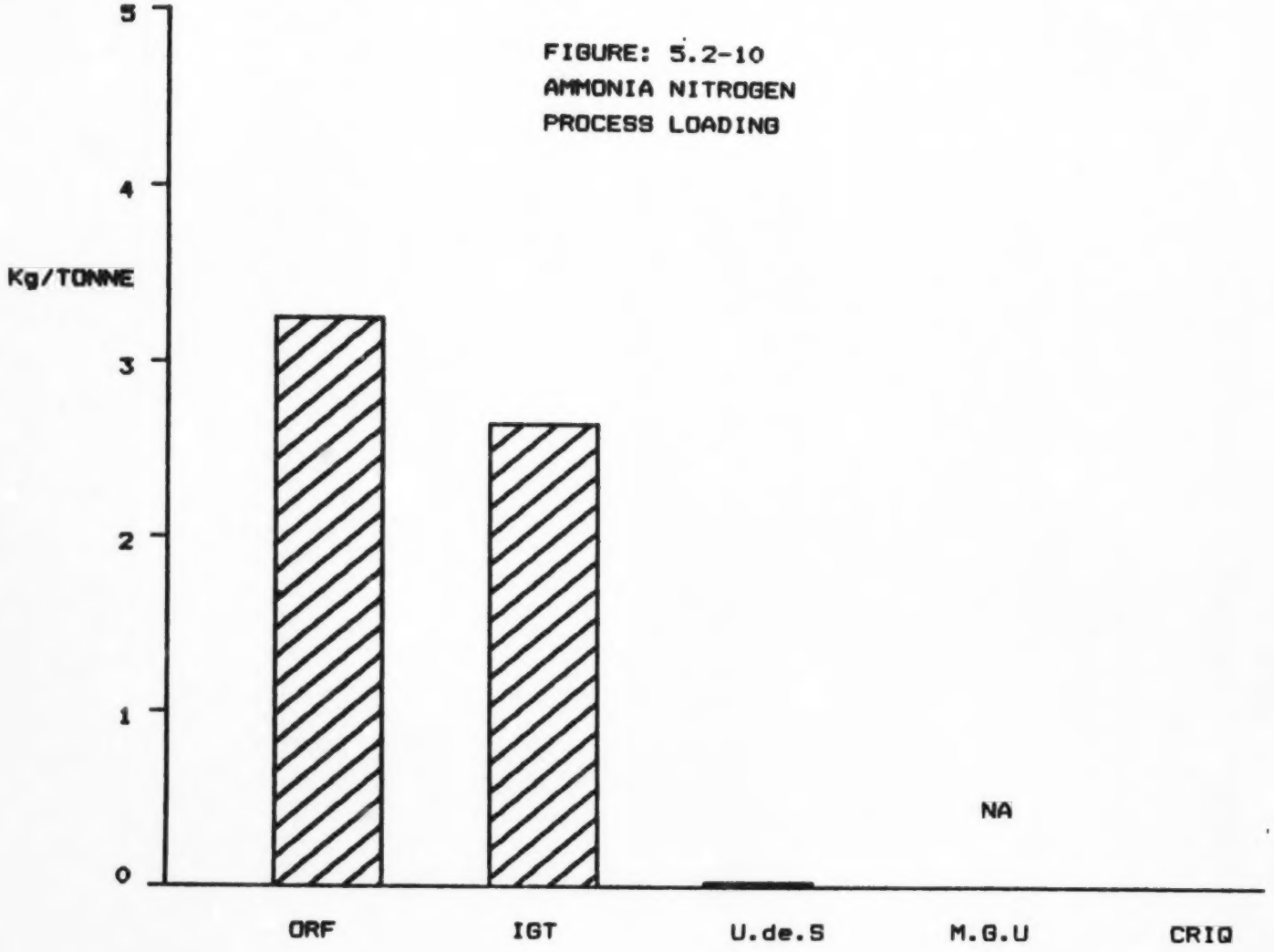


FIGURE: 5.2-11
PHENOLIC COMPOUNDS
PROCESS EFFLUENT CONCENTRATION

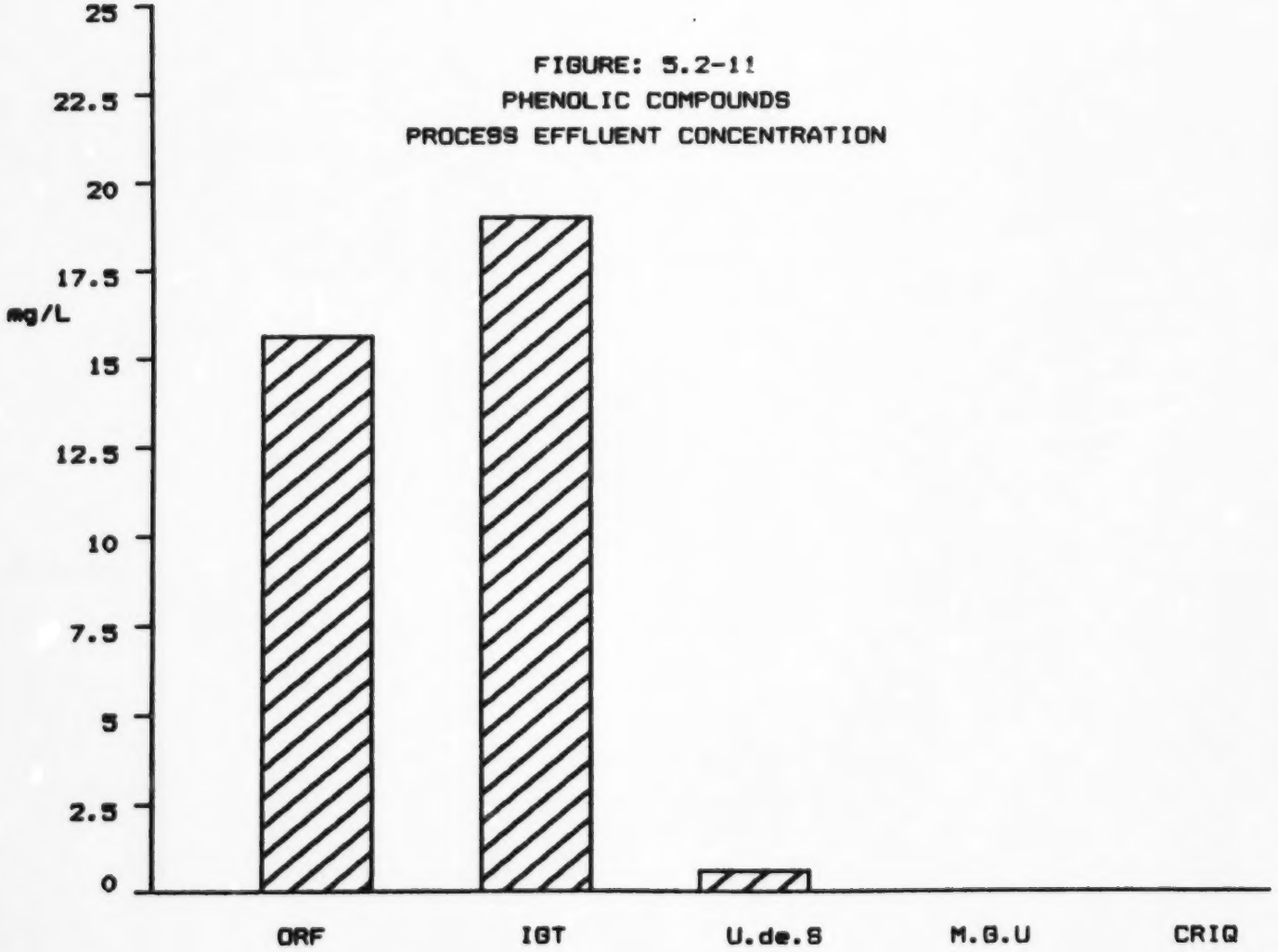


FIGURE: 5.2-12
PHENOLIC COMPOUNDS
PROCESS LOADING

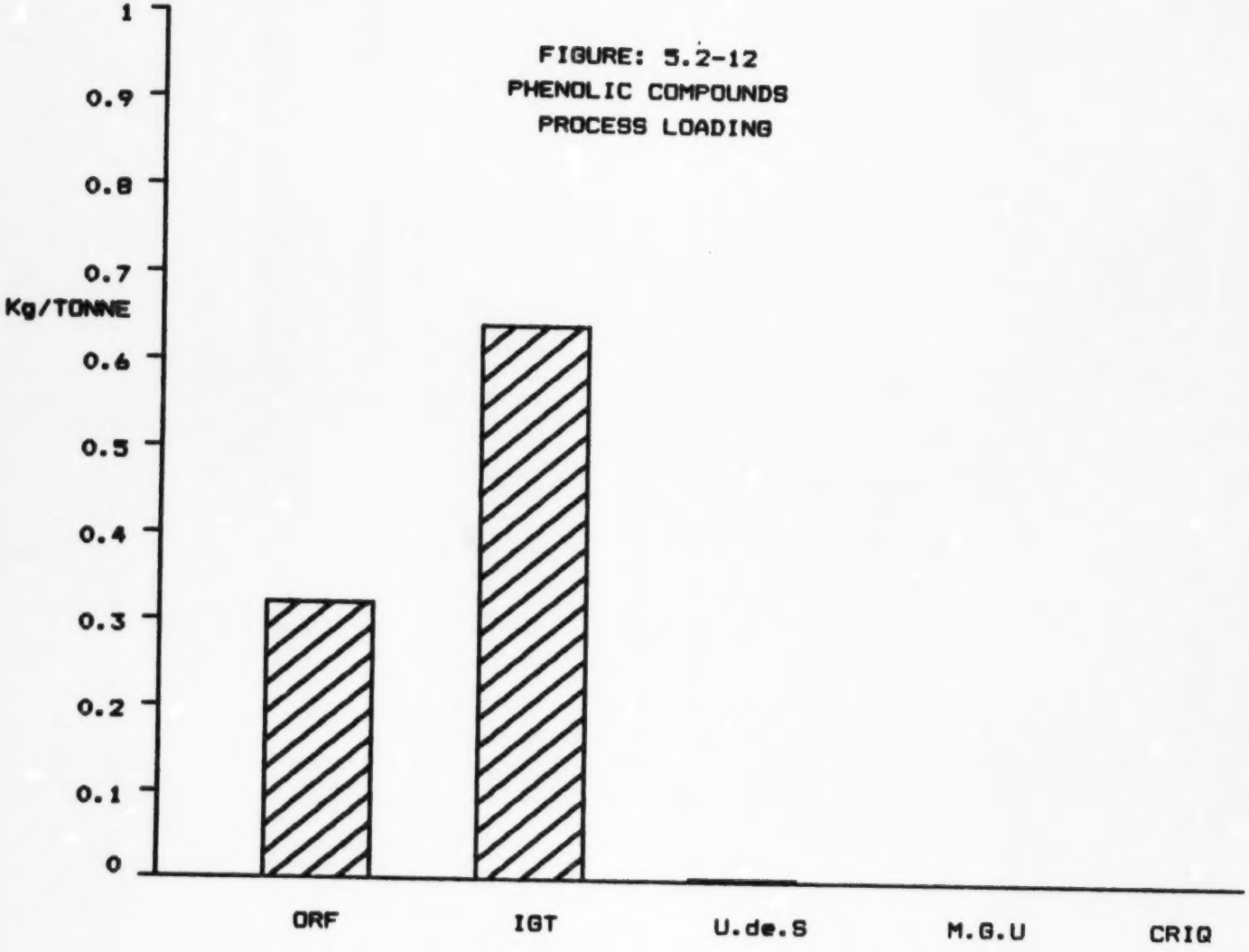


FIGURE: 5.2-13
TRUE COLOUR

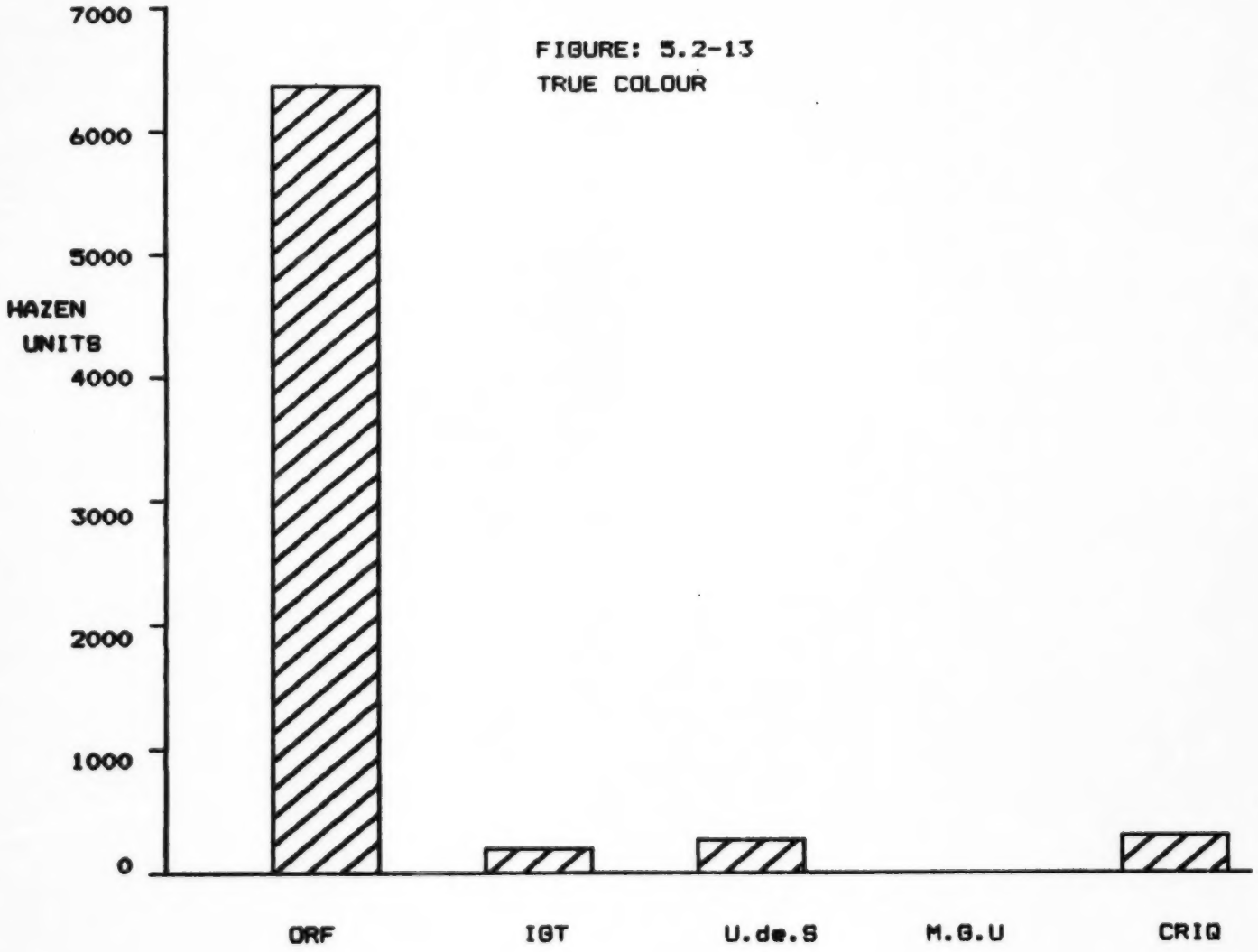


Table 5.2-1
Microbial Bioassay

Sample	As received 5 min	As received 15 min	pH=6.7 5 min	pH=6.7 15 min
ORF				
Run 1 Condensate	0.30	0.31	1.10	1.10
Filtrate(a)	0.23	0.25	1.40	1.20
Pressate(a)	0.27	0.34	1.60	1.90
Run 2 Condensate	0.54	0.45	1.10	0.60
filtrate+pressate	0.37	0.38	1.10	0.70
Run 3 Condensate	0.46	0.34	0.64	0.31
filtrate+pressate	0.40	0.48	1.00	0.80
Run 4 Condensate	0.42	0.36		
filtrate+pressate	0.35	0.40		
Run 5 Condensate	0.52	0.44		
filtrate+pressate	0.41	0.52		
Run 6 Condensate	0.16	0.15		
filtrate+pressate	0.39	0.40		
IGT				
Condensate	0.20	0.18		
Filtrate	9.00	8.90		
U. de Sherbrooke				
Filtrate	23	23		
McGill U.				
Pressate	>50	>50		
CRIQ				
Pressate	>50	>50		

(a) Fish bioassay 96hr LC50- 0.56% at as received pH
- 5.5% at 7.0-7.2 pH

6. SUMMARY AND CONCLUSIONS

6.1 ORF - Peat Wet Oxidation/Dewatering

Partial wet oxidation of peat produces a strong and acidic effluent. The effluent was characterized as particularly high in biochemical oxygen demanding substances, organic and ammonium nitrogen, and phenolic compounds. Each of these parameters was found to increase in concentration and loading (based on dry peat solids in feed) with increases in severity (reactor temperature) of peat treatment. The liquid effluents from dewatering wet oxidized peat were also highly coloured. This parameter, however, was found to decrease with increasing reactor temperature.

Wet oxidation was found to mobilize significant fractions of the metals contained in the original peats. The feed peats employed in this work, however, did not have large initial contents of potentially toxic metals.

Low levels of acid extractable priority pollutants were detected in the liquid and vapour phase effluents.

Previous work has demonstrated that the oxygen demand and ammonium contents of the peat dewatering effluents are amenable to treatment by anaerobic digestion and biological nitrification (Sheppard, Gallo and McKim, 1980). This work also demonstrated that the biologically treated effluent has a significant level of refractory COD content and remains highly coloured.

Even though the effluent from wet oxidation/dewatering of peat is known to be treatable by biological processes, it was found to be highly toxic. Microtox results in the order of 0.3% EC_{50} (confirmed by fish bioassay) were obtained.

6.2 IGT - Wet Carbonization/Dewatering of Peat

Dewatering wet carbonized Minnesota peat produced effluent with characteristics not greatly different from those of the wet oxidation of Quebec peat. Similarly, high levels of BOD_5, TKN, and phenolic compounds were recorded. The IGT filtrate was also highly coloured, though not nearly as intensely as the ORF filtrates. The wet carbonized effluents were mildly acidic.

Significant fractions of metals contained in the feed peat were mobilized by wet carbonization. This effect was mitigated by the relatively low content of toxic metals in the feed peat.

Low levels of specific phenolic compounds were determined by GC-MS.

The IGT filtrate and, particularly, the wet carbonization condensate samples were highly toxic according to their EC_{50} determinations.

The wet carbonization trial performed at the Institute of Gas Technology was determined to have been subject to the inadvertent dilution of wet carbonized product with unreacted feed peat. Thus, concentrations of contaminants in the filtrate sample may be under estimated by up to one third the actual effluent characteristics.

6.3 Université de Sherbrooke - Low-Severity Peat Dewatering Process

Filtrate from the dewatering of peat by the Université de Sherbrooke bench scale process had a modest level reported for most wastewater parameters measured. The filtrate was particularly low in suspended solids. The moderately acidic sample was highly coloured and had a fairly high microbial toxicity (EC_{50} 23%).

Much less of the metals contained in the feed peat were mobilized by the Sherbrooke process than by the other thermal processes. Iron and manganese were observed at slightly above their aesthetic criteria for drinking water. No toxic metals exceeded drinking water standards.

No acid extractable priority pollutants could be quantified in the filtrate by the analytical procedures employed.

6.6 General

Samples obtained from the bench scale processes being developed by the Université de Sherbrooke and McGill University contained very low levels of suspended solids. In this way, at least these samples are not reflective of full scale processes where solids retention is not likely to be as efficient.

Implementation of each of the pilot scale dewatering processes addressed in the study would likely require a degree of waste material recovery and/or reuse of effluent streams. For example, approximately 10% of the feed peat solids were discharged from the CRIQ rotary press. Similarly, a substantial percentage of peat organic matter is solubilized in the process of wet carbonization and of wet oxidation. These thermal processes would require the recovery of a substantial proportion of this lost matter as fuel (e.g. anaerobic digestion to methane) to achieve an acceptable overall energy balance.

7. RECOMMENDATIONS

1. Treatment of liquid effluents from the thermal pretreatment of peat prior to dewatering should be studied. A practicable method for the control of carbonaceous, nitrogenous and colour producing substances is required and should be developed, based on the recovery of by-products, e.g. ammonia and methane, from the significant fraction of the original peat contained in the waste streams.

2. The nature and origin of the high colour intensity in liquid effluents from the wet oxidation of peat should be determined. Effective ways to address this problem should be identified.

3. Components or fractions responsible for the high acute toxicity noted in a microbial bioassay (Microtox(TM)) in wet oxidized and wet carbonized liquid effluents should be isolated and characterized. The treatability of these components or fractions should be assessed.

4. The potential impacts of wastewaters released by the mechanical dewatering of peats (through suspended material, low pH, high colour intensity, etc.) on affected water sheds should be established. Remedial measures to counter predicted impacts should be designed and assessed.

5. Preparation techniques for the determination of priority pollutants in peat and peat processing samples should be developed.

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